SAMICS
Marketing & Distribution Model
Jet Propulsion Laboratory
Pasadena, California

Theodore Barry & Associates Management Consultants

TB&A

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The JPL Low-Cost Solar Array (LSA) Project is funded by DOE and forms part of the DOE Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays.

The Solar Array Manufacturing Industry Costing Standards (SAMICS) are a part of the LSA Project Analysis and Integration Activity and are intended to provide a standard procedure and data base for estimating, from descriptions of the manufacturing processes, the price at which solar modules would have to be sold to realize a specified after-tax of return on equity.

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Los Angeles • New York • Atlanta • Chicago

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We extend our sincere appreciation for the courtesy and cooperation we received from the many individuals who participated in this study for the Low-Cost Solar Array project at the Jet Propulsion Laboratory.

Mr. Robert Chamberlain deserves special recognition for his effort to develop the Solar Array Manufacturing Industry Costing Standards and his assistance in the development of this model. Mr. Chester Borden also provided several valuable suggestions for the model formulation and presentation.

SAMICS

Marketing And Distribution Model

Contents

I. EXECUTIVE SUMMARY

A. Introduction

The Jet Propulsion Laboratory (JPL) is currently managing a research and development project sponsored by the Department of Energy to reduce the cost of photovoltaic solar collectors. JPL has subcontracted the technology development to over 50 universities and manufacturing firms.

An important part of the program is the development of the Solar Array Manufacturing Industry Costing Standards (SAMICS). These standards unify economic and financial assumptions to provide comparable cost estimates for the alternative manufacturing technologies under development by the subcontractors.

Theodore Barry & Associates has been contacted to provide industrial management consulting and facilities engineering support for the development and implementation of SAMICS.

SAMICS has been formulated as a computer simulation model. Given a proper description of the manufacturing technology as input, this model computes the manufacturing price of solar arrays for a broad range of production levels. However, the ending point of the model is the loading dock of the final manufacturer. That is, the SAMICS model does not include the cost of marketing and distributing the product to the final customer and the costs of preparing the site and installing the arrays. This report presents a model for computing these marketing and distribution costs. Other models will be developed to compute the site installation and operations costs.

This marketing and distribution model is a simplification intended to recognize the added costs of marketing and transporting the solar arrays from the factory to the customer. The model covers selling, transportation, and storage costs in transit from the loading dock to the point of use.

This section presents an executive summary of the model equations and the test case results. The test case exercised the equations in the model and provides a clearer understanding of the magnitude of marketing and distribution costs in deciding the economic feasibility of photovoltaic solar collectors.

B. Marketing Model

The marketing model computes the cost of selling solar arrays. These costs include:

- Sales personnel salaries
- Office facilities cost

- Sales expenses
  - Travel and entertainment
  - Communications
  - Office supplies
- Advertising expenses

It is assumed that these costs vary for different types of customers, and the model computes the costs by type of customer. Customers are described by their average order quantity. The model allows for up to three classes of customers. For example, small residential, intermediate commercial, and large utilities. In the test case, the average residential customer purchases solar arrays in orders of 10,000 peak watts, commercial 500,000 peak watts, and utilities 50 megawatts.

The model user inputs total sales by customer by region and the average sales per unit. From these the model calculates costs. The model, restricted to the supply side, does not attempt to measure the impact on demand in a region from lower prices in that region. However, the user can measure the impact on costs of increased or reduced volume through iterations using different input data.

C. Distribution Model

The distribution model computes the cost of transporting, warehousing, and delivering the solar arrays from the factory to the final customers.

The country is divided into seven distribution regions shown in Exhibit I-1. There are two distribution alternatives for each type of customer:

1. Direct shipments from the factory to the customer.
2. Transshipments from the factory through a regional warehouse to the customer.

The model computes the alternative which minimizes the total annual distribution cost. In a given region, some types of customers may be supplied directly from the factory and others from a regional warehouse. There will not necessarily be a warehouse in every region, unless it is calculated to be economical to have one.

If there is a warehouse, the model computes the optimal warehouse size which balances the number of shipments required with the cost of operating the warehouse, thereby minimizing the cost of delivered solar modules.

D. Test Case

The validity of the model was checked by performing a test case analysis. To do this, a factory capable of producing 500 megawatts/year was assumed to be located in Region II: Rocky Mountain corresponding to Phoenix, Arizona. Exhibit I-2 shows the customer demand distribution:

Test Case Demand Distribution

- 40% residential
- 20% commercial
- 40% utility

For the test case, the manufacturing price for the solar arrays was assumed to be $.50 per peak-watt expressed in 1975 dollars. As shown in Exhibit I-3, the model results in a computed markup of about $.31 per peak watt for marketing and distribution. The results vary from region to region and by customer type.

Exhibit I-4 shows the variation in solar array price estimates for different customers by region. Since the factory was assumed to be located in the Rocky Mountain Region, the lowest cost ($.72/peak watt) would be to utility customers in the Rocky Mountain Region, while the highest cost of $.91/peak watt would be to residential customers in the Great Lakes Region. Overall, utility customers would enjoy the lowest prices ($.75/peak watt), commercial next ($.82), and finally residential ($.86) due to economies of scale in both marketing and distribution.

Exhibits I-5 and I-6 present pro forma Income Statements for SELICO, the hypothetical solar array sales and distribution company. The model forecasts were made for 1986, the test case manufacturing year. The results show gross profit of 38% and a net profit after tax of 14% compared to 40% and 14% for the SAMICS manufacturing cost estimates.

The model forecasts are adjusted for both inflation and regional differences in marketing and distribution costs.

MARKETING AND DISTRIBUTION GEOGRAPHIC REGIONS

Exhibit I-1

TEST CASE INPUT DATA

Demand Side

Market Region j \ Customer Type i		d_{ij} Customer Demand Distribution (MW/YR)			
		Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	Total Annual Demand (MW)
I	West Coast	50.0	25.0	50.0	125.0
II	Rocky Mountain	60.0	30.0	50.0	140.0
III	North Central	10.0	5.0	0.0	15.0
IV	Great Lakes	10.0	5.0	0.0	15.0
V	North Eastern	20.0	10.0	50.0	80.0
VI	South Eastern	10.0	5.0	0.0	15.0
VII	South Central	40.0	20.0	50.0	110.0
	Total	200.0 (40%)	100.0 (20%)	200.0 (40%)	500.0 (100%)

TEST CASE RESULTS

SELLCO

SOLAR ARRAY SALES AND DISTRIBUTION COMPANY

PRICE ESTIMATES

		1975 $/Watt	% Of Price
Cost of goods sold		$.500	61.9%
Expenses:			
Distribution	$.020		
Marketing	.057		
Total expenses		.077	9.5%
Income tax		.118	14.6%
Net profit		.113	14.0%
Solar array prices:			
Household products	$.864		
Commercial products	.820		
Central power stations	.747		
All products		$.808	100.0%

TEST CASE RESULTS

SOLAR ARRAY PRICE ESTIMATES

(1975 $/Watt)

Market Region j \ Customer Type i	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Customers
I West Coast	$.8595	$.8127	$.7316	$.7990
II Rocky Mountain	.8408	.8007	.7204	.7892
III North Central	.8839	.8376	-	.8685
IV Great Lakes	.9144	.8634	-	.8974
V North Eastern	.9036	.8599	.7869	.8252
VI South Eastern	.8857	.8424	-	.8713
VII South Central	.8596	.8180	.7486	.8016
All regions	$.8636	$.8201	$.7469	$.8082

TEST CASE RESULTS

SELLCO

SOLAR ARRAY SALES AND DISTRIBUTION COMPANY

INCOME STATEMENT FOR THE YEAR ENDING DECEMBER 31, 1986

		1986 $	% Sales
Sales:			
Household products	$331,251,931		42.7
Commercial products	157,295,662		20.3
Central power stations	286,492,674		37.0
Total sales		$775,040,267	100.0%
Cost of goods sold:			
Household products	$191,800,000		24.7
Commercial products	95,900,000		12.5
Central power stations	191,800,000		24.7
Total cost		479,500,000	61.9%
Gross profit		$295,540,267	38.1%
Expenses:			
Distribution (Schedule A)	$19,661,719		2.6
Marketing (Schedule B)	54,438,472		7.0
Total expenses		74,100,191	9.6
Net profit before tax		$221,440,076	28.5%
Net income tax		112,934,438	14.5
Net profit after tax		$108,505,638	14.0%

TEST CASE RESULTS

Schedule A:

	1986 $	%
Distribution expenses:		
Salaries and benefits	$ 629,095	3%
Transportation	18,650,303	95
Warehouse facilities:		
Lease		
Utilities		
Other expenses		
Total warehouse expenses	118,071	1
Inventory carrying charges	264,250	1
Total distribution expenses	$19,661,719	100%

Schedule B:

		1986 $	%
Marketing expenses:			
Salaries and benefits		$43,771,892	80%
Sales expenses		4,320,405	9
Office facilities:			
Lease	$892,162		
Utilities	42,339		
Maintenance	70,807		
Other expenses	354,067		
Total office expenses		1,359,375	2
Advertising		4,986,800	9
Total marketing expenses		$54,438,472	100%

II. MARKETING MODEL

II. MARKETING MODEL

A. General Description

This section presents the solar array marketing model assumptions and equations. Standard values to be used for the model parameters are given in Appendix B. Test case calculations and results are presented in Section V. Following are the key assumptions of the model.

The marketing model is strictly a supply side model. No attempt is made to model the interaction of supply and demand. If demand in all categories is assumed known, this procedure gives the associated marketing costs. Hence, demand is assumed to be completely inelastic or independent of the solar array price. The manufacturing cost of the solar arrays is specified as input by the user.

The country is divided into seven market regions and the total annual demand in each region is specified as input by the user. The total annual demand is assumed to be constant in each region.

Marketing costs are assumed to vary for different types of customers. Customers are described completely by their location and average order size in megawatts. The model allows for a maximum of three types of customers or products. The total demand for each customer type in each region is specified as input by the user along with the average order quantity for each customer type.

Regional sales offices are assumed to be located in every region where the demand is greater than zero. Marketing costs vary with customer location, but are assumed to be independent of the factory location. The distribution model, however, computes the cost of warehousing and delivering the product to the customer. Following is a list of input variables for the marketing model:

The following input data must be specified by the user:

AOQ_i = Average order quantity for customer type i (in megawatts per order)

for i = 1, 2, and 3

d_{ij} = Total annual demand in Region j by customers of type i (in megawatts per year)

for i = 1, 2, and 3

and j = 1, 2, ..., and 7

p = SAMICS Manufacturing Price for Solar Arrays (manufacturing year dollars/watt)

t_m = Manufacturing Year

The manufacturing year is the steady-state year for which the marketing costs are computed.

Given this input data, the model computes the total annual marketing cost in each region. The total cost consists of the following components:

Marketing Expenses	Model Symbol
Salaries and Benefits	
• Direct personnel	DSC_j
• Indirect personnel	CIS_j
Sales Expenses	SEC_j
• Office supplies	
• Travel and entertainment	
• Communications	
Office Facilities Costs	OFC_j
• Office rental	
• Utilities	
• Maintenance	
• Other expenses (property tax and insurance)	
Advertising Expenses	SAC_j
• Product A	
• Product B	
• Product C	

Exhibit II-1 shows the model personnel organization structure for the region sales and marketing office. Personnel are divided into three categories:

- Salesman
- Direct Support Personnel
- Indirect Support Personnel

The number of salesman required is determined by the total demand and average order size separately for each customer type.

The number of direct support personnel is determined by the number of salesman and average order size for each type of customer recognizing that different classes of customers have different support requirements. These include:

- Field Engineers
- Market Research Analysts
- Technical Writers
- Commercial Artists
- Technical Illustrators
- Advertising Salesman

PERSONNEL ORGANIZATION CHART

Regional Sales And Marketing Office

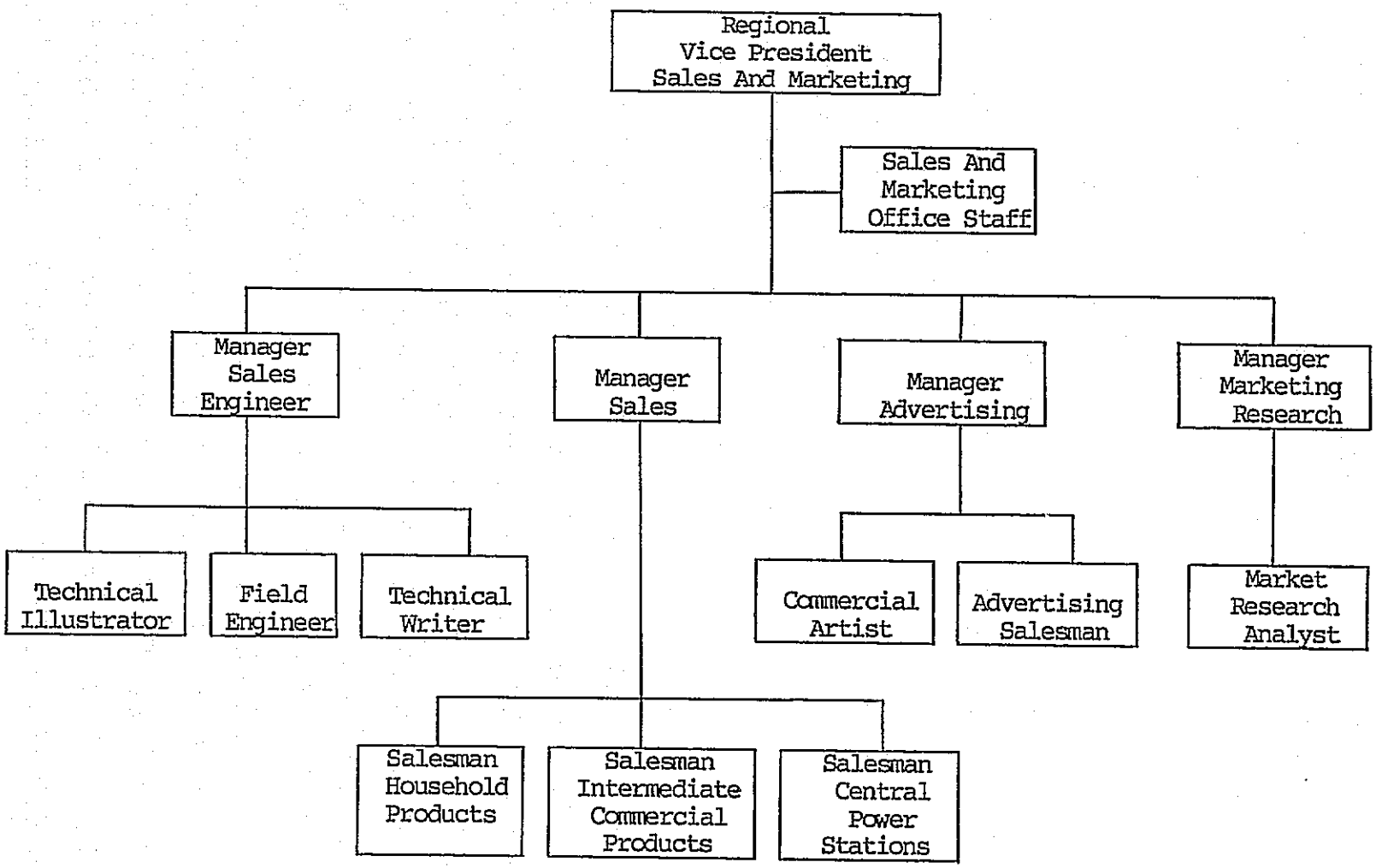


Exhibit II-1

The number of indirect support personnel are computed from the number of salesman and direct support personnel using an indirect requirements matrix.

The total annual sales cost is the sum of direct and indirect components:

DSC_j = Total Annual Direct Sales Cost in Region j (manufacturing year dollars)

ISC_j = Total Annual Indirect Sales Cost in Region j (manufacturing year dollars)

The direct sales costs consist of salaries and benefits for the salesman and direct support personnel.

The indirect sales costs consist of:

- Indirect Sales Support Personnel Cost
- Office Facilities Cost
- Sales Expenses
- Advertising Expenses

Following is a description of the parameters and underlying assumptions for the model equations to compute these costs.

B. Direct Sales Requirements

The primary determinant of selling requirements is the average order quantity per customer expressed in megawatts per order. Sales requirements are implicitly assumed to vary for different types of customers. It is assumed that this variation can be modeled through the average order size.

1. Average Order Quantity

AOQ_i = Average order quantity in megawatts for customer type i.

Note: This is specified as input by the user and is not necessarily the same as the physical delivery quantity or the total sales contract which may extend over several years. It is defined as the total sales contract for one year.

2. Salesman Productivity Assumptions

The first step in determining how many salesmen are required for a particular product-market scenario is to identify the number of orders an individual salesman can obtain per year at various levels of AOQ. Clearly, when the order quantity is small, less sales effort will be devoted to each order and each salesman will be expected to obtain more orders then if the order size were larger. At the same time, at larger values of AOQ the overall productivity of each salesman will be greater.

The basic assumptions used for computing salesman productivity are outlined below. The assumptions are predicated on the sales requirements for an established product. Although the photovoltaics industry is far from established today, this is consistent with the SAMICS steady-state assumption.

To simplify the analysis, the interaction between advertising and salesman productivity is not modeled explicitly. That is, productivity is assumed to be independent of advertising. The impact of advertising is extremely difficult to model even for established products and is beyond the scope of this model.

The user could test different relationships by varying the advertising expense rates and the salesman productivity rates for different types of customers. However, the usefulness of such results is dubious.

The specific productivity assumptions are as follows:

At very low levels of AOQ (one kilowatt per order) it is assumed that the order-taking ability of salesmen will be comparable to that of account representatives for industrial products firms, namely that each salesman can make an average of 1750 calls per year and obtain one order for every 3.5 calls. Hence, for an average order quantity of .001 MW, each salesman averages 500 orders per year.

It is further assumed that at the level of 10 MW per order and above, approximately one salesman is required for every order obtained. Through linear interpolation an equation is thus designed to yield the value for any level of AOQ.

AOQ Average Order Quantity (MW)	OPS Orders Per Salesman (Orders/YR)	MWS Megawatt Sales Per Salesman (MW/YR)
.000	0.00	.00
.001	500.00	.50
.010	51.00	.51
.100	5.90	.59
1.000	1.45	1.45
10.000 and above	1.00	10.00 or more

Note: The intermediate points in this table are interpolations, not breakpoints on a piecewise linear function.

The size of a typical residential unit could range from 1 kilowatt (.001 MW) to 10 kilowatts (0.010 MW) depending upon the application. For example, 1 kilowatt would provide electricity for a water heater while 10 kilowatts would be required to supply all of the household's electrical needs.

Thus, the productivity relationships imply that a salesman could sell 500 solar water heating units in a year or 50 larger household electrical units.

Solar units of 10 MW or more would be purchased by public or private utilities for central power stations. Based on experience with the utility industry, a single salesman can typically make one large sale per year.

3. Annual Megawatt Sales Per Salesman

Assuming a piece-wise linear relationship between annual megawatt sales per salesman and the average order quantity per customer, the following equations correspond to the data presented in the table above.

MWS = Annual megawatt sales per salesman to customer type i

$$MWS = \begin{cases} 500*AOQ & \text{for } 0 \leq AOQ \leq .001 \\ .4999 + .9501*AOQ & \text{for } 0.001 < AOQ < 10.000 \\ AOQ & \text{for } AOQ \geq 10.000 \end{cases}$$

The coefficients are expressed to 4 decimal digits so that substitution will yield the results presented in the table. They do not reflect the degree of accuracy of the linear productivity assumptions.

4. Size Of The Sales Force

The number of salesmen required is computed separately for each type of customer based on the total annual demand and the salesmen productivity ratio. The total annual demand in each region and the average demand per customer are assumed to be known and constant over time for each customer type.

d_{ij} = Total annual demand in Region j by customers of type i (MW/Year)

SR_{ij} = Total number of salesman required in Region j for customers of type i

$$SR_{ij} = \frac{d_{ij}}{MWS_i}$$

5. Salesman Support Index

Direct sales support personnel include:

- Field Engineers
- Market Research Analysts
- Technical Writers
- Commercial Artists
- Technical Illustrators
- Advertising Salesman

The amount of direct support per salesperson is assumed to depend on the type of customer as follows:

ACQ Average Order Quantity (MW)	SSI Salesman Support Index
0.000	0.00
.001	0.10
1.000	0.19
10.000	1.00
100.000	5.00

SSI = Salesman support index for customer type i

$$SSI = \begin{cases} 100*ACQ_i & \text{for } 0 \leq ACQ_i \leq .001 \\ .0999 + .0900*ACQ_i & \text{for } .001 < ACQ_i \leq 10 \\ .5556 + .0444*ACQ_i & \text{for } ACQ_i > 10 \end{cases}$$

These equations correspond to the data presented in the table above (assuming a piece-wise linear relationship). The coefficients are expressed to 4 decimal digits so that the linear segments intersect at the breakpoints. This does not indicate the degree of accuracy in the estimates.

The number of direct sales support personnel required is computed by multiplying the number of salesmen by the support index by a requirement coefficient for each type of personnel.

DSP_j = Total direct sales support personnel required in Region j

$$= \sum_{k=1}^{6} \sum_{i=1}^{3} RC_k * SSI_i * SR_{ij}$$

where

RC_k = Requirement coefficient for direct support personnel of type k

Index k	Description	Annual Compensation* AC_k	Requirement Coefficient RC_k
1	Field Engineer	$26,400	2.0
2	Commercial Artist	12,320	.1
3	Market Research Analyst	25,200	.4
4	Technical Illustrator	18,900	.2
5	Technical Writer	18,900	.2
6	Advertising Salesman	17,500	.1

*Expressed in 1977 dollars.

The requirement coefficients indicate the number of direct support personnel required per salesman when the salesman support index is one. This corresponds to an average order quantity per customer of 10 MW. It is assumed that the sales support required for customers of this size is equivalent to that for a small public utility.

6. Total Direct Sales Personnel Cost

DSC_j = Total direct sales cost in Region j (in manufacturing year dollars)

$$= \sum_{i=1}^{3} SR_{ij} * CS_i * l_j * (1+g_B)^n$$

$$+ \sum_{k=1}^{6} \sum_{i=1}^{3} RC_k * SSI_i * l_j * SR_{ij} * AC_k * (1+g_B)^n$$

This can be expressed more simply as:

$$DSC = \left[\sum_{i=1}^{3} SR_{ij} * (CS_i + SSI_i * \sum_{k=1}^{6} RC_k * AC_k)\right] * l_j * (1+g_B)^n$$

where

l_j = Labor cost index in Region j
g_B = Labor cost inflation rate
n = (Manufacturing Year)-(Base Price Year)
AC_k = Annual compensation rate for direct sales personnel type k (Base Price Year $/Year)
CS_i = Annual compensation rate for salesman type i (Base Price Year $/Year)

Standard values to be used for these parameters are presented in Appendix B.

C. Indirect Sales Requirements

1. Indirect Sales Support Personnel Submodel

Indirect sales support personnel are assumed to include the following:

- Regional Vice President Sales and Marketing
- Manager, Advertising
- Manager, Marketing Research
- Manager, Sales
- Manager, Sales Engineering
- Secretary I (lower management)
- Secretary II (middle management)
- Secretary III (upper management)

The number required is determined from the number of salesmen and direct sales staff following the line-staff relationships indicated on the organization chart and the indirect requirements matrix as follows:

ISP = Total indirect sales support personnel (a vector) required in Region j

$$= D + R\ D + R\ (R\ D) + R^3 D + \ldots$$

where

R = Indirect personnel requirements matrix
D = Direct personnel requirements vector for Region j

The indirect requirements matrix coefficients are presented in Appendix B.

The compensation rates for all indirect sales support personnel are also given in Appendix B to be used for computing indirect personnel costs.

CIS_j = Annual indirect sales personnel cost in Region j (in manufacturing year dollars)

$$= \sum_i (ISP_{ij} * Salary_i) * l_j * (1 + g_B)^n$$

2. Office Facilities Cost Submodel

Office facility costs include:

- Office rental
- Utilities
- Maintenance
- Other expenses (property tax and insurance)

Office rental consists of the buildings, furniture, fixtures, and equipment. The amount of space required is determined by the number of people. The equations for Sales Office Facility Costs are presented below. Standard values to be used for each of the parameters are given in Appendix B.

OS_j = Sales office size in Region j (square meters)
= $(DSP_j + ISP_j)*SPP$

where
SPP = Amount of office space per person (square meters/person)

The total annual office facilty costs in Region j are computed from the following relationship:

OFC_j = Total annual office facility costs in Region j (Manufacturing Year Dollars)
= $ORC_j + OUC_j + OMC_j + OOC_j$

where
ORC_j = Office Rental Expense in Region j (Manufacturing Year $/Year)
OUC_j = Office Utilities Expense in Region j (Manufacturing Year $/Year)
OMC_j = Office Maintenance Expense in Region j (Manufacturing Year $/Year)
OOC_j = Other Office Expenses in Region j (Manufacturing Year $/Year)

Note that the amount of office space per person has been expressed as a constant for all types of personnel. Actually, different personnel require different amounts of space. However, these differences are not important. For the purposes of this model, an average figure will provide a good enough estimate of the office space because the personnel mix remains homogeneous at all levels of sales.

- Office Rental Expense Submodel

$$ORC_j = b_j * K_o(OS_j) * \gamma_o * (1+g_H)^n$$

where
b_j = Facilities Cost Index for Region j

OS_j = Sales Office Size in Region j

$K_o(OS_j)$ = Office Facilities Capital Cost Function

γ_o = Office Facilities Lease Rate

g_H = Facilities Inflation Rate (%/year)

n = (Manufacturing Year) - (Base Price Year)

- Office Utilities Expense Submodel

$$OUC_j = u_j * \rho_o * OS_j * (1+g_E)^n$$

where

u_j = Utilities Cost Index for Region j

ρ_o = Office Utilities Cost Rate ($/square meter)

OS_j = Sales Office Size in Region j (square meters)

g_E = Utilities Inflation Rate (%/year)

n = (Manufacturing Year) - (Base Price Year)

- Office Maintenance Expense Submodel

$$OMC_j = m * b_j * K_o(OS_j) * (1+g_H)^n$$

where

m = Office Maintenance Cost Rate (% of Capital Cost)

b_j = Facilities Capital Cost Index for Region j

$K_o(OS_j)$ = Office Facilities Capital Cost Function

g_H = Facilities Inflation Rate (%/year)

n = (Manufacturing Year) - (Base Price Year)

Note: Although maintenance costs are more labor intensive than capital costs, it is assumed that the total maintenance requirement depends on the capital cost of the office facilities. Capital costs include materials, construction labor, and architectural and engineering design fees. Furthermore, office maintenance represents a relatively small portion of the total sales office facilities cost. Thus, the office maintenance expense is not adjusted by the labor cost index for differences in regional labor costs or by the labor cost inflation rate.

- Other Office Expenses Submodel

$$OOC_j = (\beta + \lambda) * b_j * K_o(OS_j) * (1+g_H)^n$$

where

β = Property Tax Rate (% of Capital Cost)

λ = Insurance Rate (% of Capital Cost)

3. Sales Expense Submodel

Sales expenses include:

- Office supplies
- Travel and entertainment
- Communications

These expenses are assumed to vary with the type of customer and are computed as a function of the direct cost of salesmen.

SEC_i = Annual Sales Expense Cost in Region j (Manufacturing Year Dollars)

$$= \sum_{i=1}^{3} SAE_i * SR_{ij} * CS_i * l_j * (1+g_B)^n$$

where

SAE_i = Sales Expense Rate associated with the salesmen who sell to Customer Type i

4. Advertising Expenses Submodel

Since this is a supply side model, the intent of the advertising expenses submodel is to prescribe a reasonable estimate of the advertising budget rather than to model the optimal advertising budget. The impact of advertising is extremely difficult to model even for established products and is beyond the scope of this model.

Thus, the size of the advertising budget is computed as a function of the cost of the product for each customer type. This allows the user to specify different advertising rates for different types of customers.

The submodel is expressed symbolically as follows:

SAC_j = Annual Advertising Cost in Region j (Manufacturing Year Dollars)

$$= \sum_{i=1}^{3} ADE_i * p * d_{ij} * 10^6$$

where

ADE_i = Advertising Rate (% of Manufacturing Price) for Customer Type i

p = SAMICS Manufacturing Price for Solar Arrays (Manufacturing Year $/watt)

d_{ij} = Annual Demand in Region j by all customers of type i (megawatts/year)

10^6 = Conversion Factor (watts/megawatt)

Standard values to be used for the advertising rate, ADE_j) are given in Appendix B. The standard rates vary inversely with the cost of the product. That is, the advertising budget rate for small residential customers is higher than for large central power station customers.

The following rules of thumb were used to establish the standard values:

Firms typically allocate between 1% and 2% of sales to advertising. Of course this varies among industries. The percentage was nearly 5% for tobacco companies and .7% for food retailers in 1977.

5. Total Indirect Sales Costs

The total annual indirect sales costs are computed as the sum of indirect sales personnel, office facility, sales expense, and advertising costs in Region j.

ISC_j = Total Indirect Sales Cost in Region j (in manufacturing year dollars)

$$= CIS_j + OFC_j + SEC_j + SAC_j$$

where

CIS_j = Annual indirect sales personnel cost in Region j (manufacturing year dollars)

OFC_j = Annual Office Facility Costs in Region j (manufacturing year dollars)

SEC_j = Annual Sales Expense Cost in Region j (manufacturing year dollars)

SAC_j = Annual Advertising Cost in Region j (manufacturing year dollars)

III. DISTRIBUTION MODEL

III. DISTRIBUTION MODEL

A. General Description

This section presents the solar array distribution model assumptions and equations. Standard values to be used for the model parameters are given in Appendix C. Test case calculations and results are presented in Section V.

The purpose of the distribution model is to compute the cost of distributing solar arrays from the manufacturing plant to the final customer.

To do this, the country is divided into seven geographic areas with one regional warehouse distribution center in each area. Exhibit III-1 gives the location of the distribution centers.

The model assumes a single factory whose regional location is specified by the user. Multiple factory locations can be modeled by restricting the distribution demand and making separate runs for each factory.

For a given manufacturing factory the distribution demand is specified as input. The demand is described in total megawatts per year in each Region j by customer type i, (d_{ij}), and in megawatts per shipment by customer type i, (q_i). The model allows for a maximum of three types of customers and seven distribution regions.

For each combination of customer type and distribution region, there are two distribution alternatives:

- Direct shipments from the factory to the customer.
- Transshipments from the factory through a regional warehouse to the customer.

The model computes the least cost distribution alternative for each type of customer in each region based on their assumed demand. Thus, some regions may have warehouses and others may not. Furthermore, some customers in a region may be supplied directly from the factory and others from a local warehouse.

The size of the regional warehouses is optimized by computing the economic warehouse order quantity based on their assumed demand. This balances the number of shipments with the size of the warehouse. Transportation costs are reduced by having larger warehouses requiring fewer shipments. However, warehouse operating and inventory holding costs are higher. The problem is to compute the warehouse order quantities for each customer to minimize the total annual distribution cost.

REGIONAL WAREHOUSE DISTRIBUTION CENTERS

Region	Geographic Area	Distribution Center
I	West Coast	Los Angeles
II	Rocky Mountain	Phoenix
III	North Central	Omaha
IV	Great Lakes	Springfield
V	North Eastern	Syracuse
VI	South Eastern	Atlanta
VII	South Central	Dallas

Distribution costs consist of the following components:

Distribution Expenses

- Salaries and benefits
- Transportation costs
- Warehouse facility costs
  - Building lease
  - Utilities
  - Other expenses
- Inventory carrying charges

Transportation costs vary with weight rather than volume. For a given weight, the model determines the least cost transportation mode.

Exhibit III-2 illustrates the relationship between cost, mode, and shipment weight. Transportation costs are assumed to depend only on distance and weight and are independent of the geographic relationship between the origin and destination.

It is assumed that the manufacturer has a finished goods warehouse at the factory and that the associated costs are part of the manufacturing price.

The warehouse inventory model for the regional distribution centers assumes uniform, deterministic demand over time. Penalty costs for stockouts are assumed to be sufficiently high so that stockouts are not allowed. This implies that the warehouse must be large enough to supply all demand on time. Furthermore, there are no manufacturing price discounts for large order quantities, although the distribution price is lower.

The distribution model requires the following input data from the user:

Input Data

v = Solar array volume (cubic meters/megawatt)

w = Solar array weight (kilograms/megawatt)

t_m = Manufacturing year

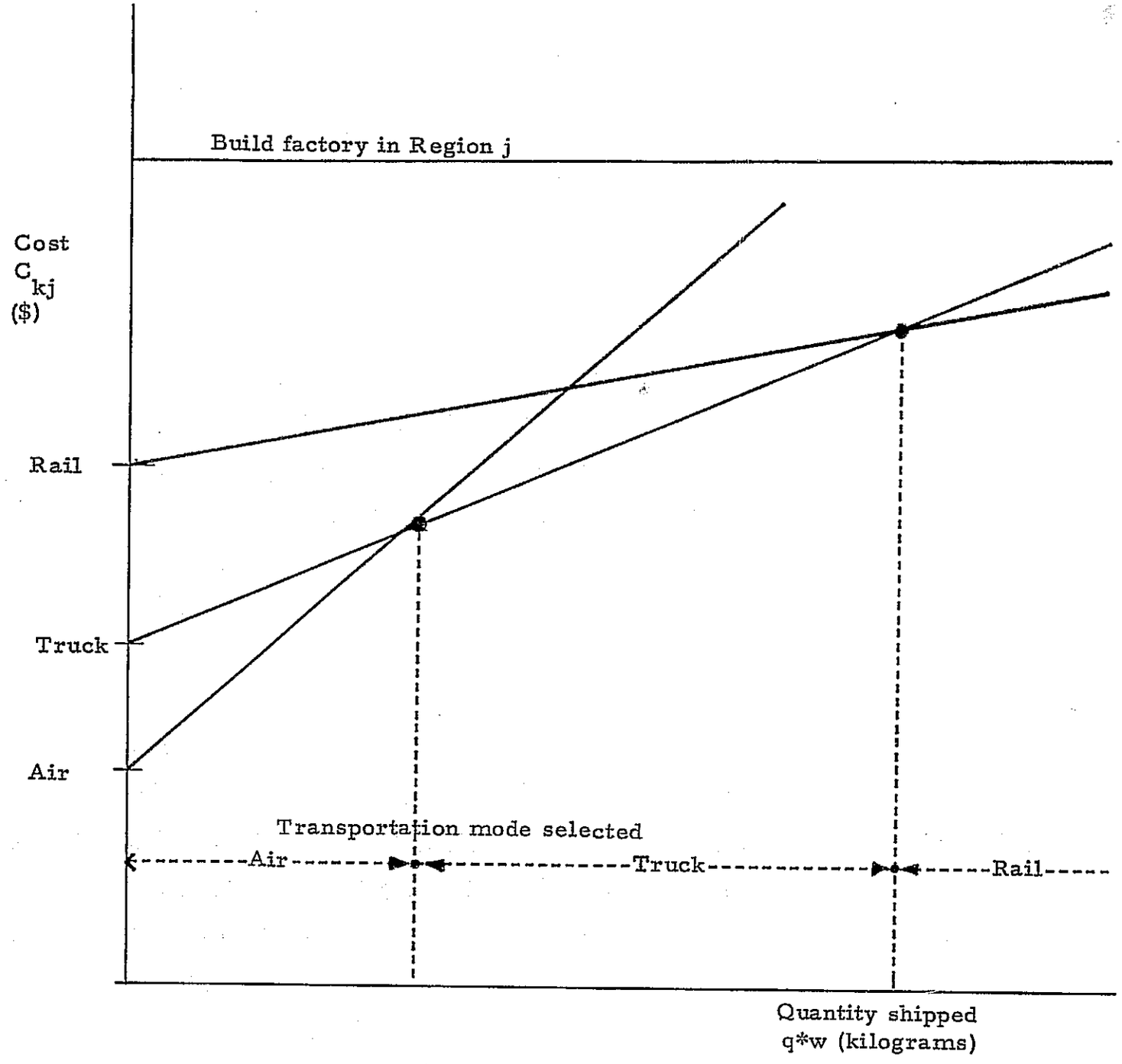
p = SAMICS Manufacturing Price for solar arrays (manufacturing year dollars/watt)

k = Factory Location Region

q_i = Average delivery quantity for customers of type i (megawatts/shipment)

for i = 1, 2, and 3

FACTORY-CUSTOMER TRANSPORTATION COSTS
From Region k to Region j



The numerical details of this function depend on the average distance between k and j and the weight of the product shipment.

d_{ij} = Annual demand in Region j by all customers of type i (megawatts/year)

for i = 1, 2, and 3

and j = 1, 2, 3,...,7

y_{ij} = Average distance from the warehouse to the delivery location for customer type i in Region j (kilometers)

From this input, the model computes the total annual distribution cost for each region. This corresponds to the least cost combination of direct shipments and warehouse transshipments and the economic warehouse size.

Output

X_{ij}^* = { 0 if customers of type i in Region j are supplied directly from the factory; 1 if customers of type i in Region j are supplied from a warehouse in Region j

F_j^* = Optimal warehouse size in Region j (square meters)

Q_j^* = Optimal warehouse order quantity in Region j (megawatts/shipment)

$$\text{Total cost} = IC_{kj}(Q_j^*) + DC_{kj}$$

where

DC_{kj} = Annual Distribution Cost in Region j for customers supplied directly from the factory in Region k (manufacturing year dollars)

$IC_{kj}(Q_j^*)$ = Annual Distribution Cost in Region j for customers supplied from a regional warehouse in Region j with transshipments from the factory in Region k (manufacturing year dollars)

The optimal warehouse order quantity, Q_j^* is determined by varying the order quantity parametrically (over a broad range), computing the corresponding warehouse size and distribution costs for each quantity, and selecting the quantity which yields the lowest annual distribution cost. This is repeated for all possible combinations of direct and indirect shipments, X_{ij}. The optimal value X_{ij}^* is the combination which yields the lowest total cost. The corresponding warehouse order quantity is the optimal value, Q_j^*.

Following is a description of the parameters and underlying assumptions for the model equations to compute these costs.

B. Direct Factory - Customer Shipments

If there is a warehouse in Region j (that is, if $X_{ij} = 1$), all deliveries to customers of type i in Region j go thru the warehouse. All other customers (that is, if $X_{ij} = 0$) are supplied directly from the factory.

The cost of supplying customers directly from the factory is given by the following relationship:

$$DC_{kj} = \sum_{i=1}^{3} \frac{d_{ij}}{q_i} * (1-X_{ij}) * C(Z_{ij}, S_{kj})(1+g_T)^n$$

where

DC_{kj} = Annual distribution cost in Region j for customers supplied directly from the factory in Region k (in Manufacturing Year Dollars/year)

d_{ij} = Annual demand in Region j by all customers of type i (megawatts/year)

X_{ij} = $\begin{cases} 0 & \text{if customers of type i in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$

g_T = Transportation inflation rate

n = (Manufacturing Year) - (Base Price Year)

q_i = Average delivery quantity for customers of type i (megawatts/delivery)

w = Solar array weight (kg/megawatt)

Z_i = Average shipment weight to customers of type i (kilograms/delivery)

= $q * w$

s_{kj} = Average shipping distance from Region k to Region j (kilometers)

$C(Z_i, s_{kj})$ = Interregional transportation cost as a function of the shipment weight, Z_i and distance, s_{kj}. This is a table look-up function presented in Appendix C. The transportation mode is optimized by quantity ordered, but regional geography is not considered.

C. Factory-Warehouse Transshipments

The cost of supplying demand in Region j from a regional warehouse is composed of three parts:

- Factory-Warehouse Transportation Cost

  The cost of transporting the product in bulk from the factory in Region k to the warehouse in Region j. This is a function of the distance and the economic shipment quantity and includes the cost of processing the order.

- Warehousing Costs

  This consists of inventory carrying costs, warehouse operating costs, and warehouse capital costs.

- Delivery Costs

  This is the cost of distributing individual units from the warehouse to the customers.

Given the total demand in Region j by each type of customer, d_{ij}, the first two cost functions must be optimized to determine the economic warehouse order quantity. This balances the number of shipments with the size of the warehouse. It is assumed that the penalty cost associated with stockouts is sufficiently high that stockouts are not allowed. (This would likely be the case, for example, if the customer - not merely the sale - were lost if the product could be delivered on time.)

The annual demands, d_{ij}, the average delivery quantities, q_i, and the solar array weight, w, are input variables whose values are specified by the user.

The interregional shipping distances and the transportation cost function are standard data whose values are listed in Appendix C. The cost function is a piecewise linear function of the quantity shipped and the distance traveled. X_{ij} is a decision variable whose value is determined to minimize total annual distribution costs. This determines which customers are supplied from the factory and which are supplied from a regional warehouse.

$IC_{kj}(Q_j)$ = Total annual distribution cost for Region j warehouse transshipments from the factory in Region k as a function of the warehouse order quantity Q_j (in Manufacturing Year Dollars)

$$= T_{kj}(Q_j) + W_j(Q_j) + L_j$$

where

$T_{kj}(Q_j)$ = Annual transportation cost for shipments from the factory in Region k to the warehouse in Region j as a function of the order quantity Q_j (in Manufacturing Year Dollars)

$W_j(Q_j)$ = Annual warehousing cost in Region j (in Manufacturing Year Dollars)

L_j = Annual delivery cost in Region j (in Manufacturing Year Dollars)

1. Factory-Warehouse Transportation Cost

$$T_{kj}(Q_j) = \frac{\sum_{i=1}^{3} d_{ij} * X_{ij}}{Q_j} [OP + C(Q_j * w, s_{kj})] (1+g_T)^n$$

where

Q_j = Factory Warehouse Shipment Quantity in Region j (megawatts)

d_{ij} = Annual demand by all customers of type i in Region j (megawatts/year)

X_{ij} = 0 if customers of type i in Region j are supplied directly from the factory
1 if customers of type i in Region j are supplied from a warehouse in Region j

OP = Order processing cost ($/shipment)

w = Solar array weight (kilograms/megawatt)

s_{kj} = Average shipping distance from Region k to Region j (kilometers)

$C(Q_j*w, s_{kj})$ = Interregional transportation cost as a function of the shipment weight and distance

g_T = Transportation Inflation Rate

n = (Manufacturing Year) - (Base Price Year)

2. Warehouse Costs

$W_j(Q_j)$ = Annual warehousing cost in Region j as a function of the order quantity Q_j (in manufacturing year dollars)

= $CC(Q_j) + OC_j(Q_j) + LC_j(Q_j)$

$CC(Q_j)$ = Annual inventory carrying cost as a function of the warehouse order quantity in Region j (in manufacturing year dollars)

$OC_j(Q_j)$ = Annual warehouse operating cost in Region j as a function of the order quantity, Q_j(in manufacturing year dollars)

$LC_j(Q_j)$ = Annual warehouse leasing cost in Region j as a function of the warehouse order quantity Q_j (in manufacturing year dollars)

a. Inventory Carrying Cost

$$CC(Q_j) = (Q_j/2) * p * \beta * 10^6 \quad (\$/\text{year})$$

where

Q_j = Factory-warehouse shipment quantity in Region j

Note: $(Q_j/2)$ = Average inventory level assuming zero safety stock and uniform demand over time. Given a deterministic demand, this assumption minimizes the warehouse costs.

p = SAMICS manufacturing price for Solar Arrays ($/watt) i.e., the unit value of inventory in manufacturing year dollars

β = Annual inventory carrying charge as a % of unit value

10^6 = Conversion factor (watts/megawatt)

b. Warehouse Operating Cost

Operating costs include personnel, utilities, maintenance, property tax, and insurance on the building and equipment.

$$OC_j(Q_j) = PC_j + UC_j + XC_j + SC_j + MC_j$$

PC_j = Personnel Cost = $l * P(F_j) * (1+g_B)^n$

UC_j = Utilities Cost = $\rho_w * U_j * F_j * (1+g_E)^n$

XC_j = Property Tax Cost = $\beta_w * [e_j * K_e(F_j) * (1+g_j) + b_j * K_b(F_j)(1+g_H)^n]$

SC_j = Insurance Cost = $\mu_w * [e_j * K_e(F_j) * (1+g_j) + b_j * K_b(F_j)(1+g_H)^n]$

MC_j = Maintenance Cost = $m * [e_j * K_e(F_j) * (1+g_j) + b_j * K_b(F_j)(1+g_H)^n]$

where

l_j = Labor Cost Index for Region j

g_B = Labor Inflation Rate (%/year)

u_j = Utility Cost Index for Region j

g_E = Utilities Inflation Rate (%/year)

e_j = Equipment Cost Index for Region j

g_J = Equipment Inflation Rate (%/year)

b_j = Building Cost Index for Region j

g_H = Facilities Inflation Rate (%/year)

ρ_w = Utility Cost Rate ($/square meter/year)

β_w = Property Tax Rate (% of capital cost/year)

υ_w = Insurance Rate (% of capital cost/year)

m = Maintenance Cost Rate (% of capital cost/year)

F_j = Warehouse size in Region j as a function of the warehouse order quantity (square meters)

Note: This is a piece-wise linear function of the order size, Q_j, and is derived in Appendix C.

$P(F_j)$ = Personnel Cost Function ($/year) includes both wages and benefits

$K_e(F_j)$ = Equipment Capital Cost Function

$K_b(F_j)$ = Building Capital Cost Function

n = (Manufacturing Year) - (Base Price Year)

Warehouse Size

The size of the regional warehouses is a function of the economic or optimal factory-warehouse order quantity, Q^*_j, the physical volume of the solar array modules, j, and the warehouse space utilization factor, α. This is a piece-wise linear function of Q and is derived in Appendix C.

F_j = Warehouse size in Region j (Square meters)

$F^*_j = \alpha * v * Q_j$ (Table look-up function of Q)

where

Q = Factory-warehouse shipment quantity in Region j (megawatts)

v = Solar array volume (cubic meters/megawatt)

α = Warehouse space utilization factor

The utilization factor adjusts for the stacking height and the amount of space required for circulation and offices. A standard value for this parameter is derived in Appendix C.

c. Warehouse Leasing Cost

Annual warehouse leasing costs are computed separately for plant and equipment based on the economic lives and the lessor's rate of return.

$LC_j(Q_j)$ = Annual warehouse leasing cost in Region j as a function of the warehouse order quantity Q_j

$LC_j(Q_j) = \gamma_e * K_e(F_j) * e_j (1+g_J)^n + \gamma_b * K_b(F_j) * b_j * (1+g_H)^n$

e_j = Equipment Cost Index

b_j = Building Cost Index

γ_e = Annual lease Rate for Equipment (fraction of capital cost/year)

g_j = Equipment Inflation Rate (%/year)

n = (Manufacturing Year) - (Base Price Year)

γ_b = Annual lease Rate for Building (fraction of capital cost/year)

g_H = Facilities Inflation Rate (%/year)

F_j = Warehouse size in Region j (square meters) as a function of the order quantity Q

$K_e(F_j)$ = Equipment Capital Cost Function

$K_b(F_j)$ = Building and Land Capital Cost Function

3. Customer Delivery Costs

Based on an analysis of local freight carriage costs in different regions of the U.S., transportation costs from the warehouse to the customers can be minimized when the company owns and operates a fleet of delivery trucks. The costs of owning and operating a delivery truck are divided into fixed and variable components. Fixed costs include drivers' wages and benefits, vehicle capital charges, depreciation, and insurance. Variable costs per kilometer consist of gas, oil, and maintenance. The following are formulas for computing these costs and the fleet size required.

L_j = Total Annual Local or Intraregional Delivery Costs in Region j (in manufacturing year dollars)

$= [TK * FC + VC * KM](1+g_T)^n$

where

TK = Vehicle Fleet Size (vehicles)

FC = Annual Fixed Cost per vehicle ($/vehicle-year)

VC = Variable Operating Cost per vehicle-kilometer ($/kilometers)

KM = Total distance traveled (kilometers/year) by all vehicles

g_T = Transportation Inflation Rate (%/year)

n = (Manufacturing Year) - (Base Price Year)

The fleet size and total distance traveled are given by the following relationships:

Fleet Size Submodel

The number of regional delivery trucks required is computed by dividing the total travel distance by the vehicle distance capacity.

$$TK = \frac{KM}{MC} \quad \text{(rounded up to an integer value)}$$

Travel Distance Submodel

The total travel distance by all delivery trucks in a given region is computed as follows:

KM = Total Distance Traveled by all vehicles (kilometers/year)

= (# Tours) * (Distance per tour)

$$= \frac{(\#\ \text{Customers})}{(\#\text{Customers/Tour})} * (\text{Distance per tour})$$

$$\#\ \text{Customers} = \frac{d_{ij} * X_{ij}}{q_i}$$

$$\#\ \text{Customers/Tour} = \frac{WC}{q_i * w}$$

$$\text{Distance/Tour} = y_{ij} * \left(\frac{WC}{q_i * w}\right) + y_{ij}$$

$$KM = \sum_{i=1}^{3} \left(\frac{d_{ij} * X_{ij}}{q_i}\right)\left(\frac{q_i * w}{WC}\right)\left(1 + \frac{WC}{q_i * w}\right) y_{ij}$$

$$KM = \sum_{i=1}^{3} \frac{d_{ij}}{q_i} * X_{ij}\left(1 + \frac{q_i * w}{WC}\right) * y_{ij}$$

$$X_{ij} = \begin{cases} 0 & \text{if customers of type } i \text{ in Region } j \text{ are supplied directly from the factory} \\ 1 & \text{if customers of type } i \text{ in Region } j \text{ are supplied from a warehouse in Region } j \end{cases}$$

WC = Vehicle Load Capacity (kilograms/shipment)

w = Solar Array Weight (kilograms/megawatt)

y_{ij} = Average distance from the warehouse to the delivery location for customer type i (kilometers) in Region j

The average delivery distance, y_{ij} , is specified as input by the user and can be used to model differences in the customer location distribution between regions and/or types of customers. A constant value of 50 kilometers for all regions and customers was used for the test case presented in Section V.

Appendix C contains standard values for the fixed cost, variable operating cost, distance capacity, and load capacity for medium sized trucks.

IV. FINANCIAL MODEL

A. General Description

The financial model of the firm consists of the equations used to compute sales revenues, taxes, and profit based on the marketing and distribution expenses.

The model parameters are expressed in the standard financial statement terms to facilitate the preparation of projected income statements for each region.

The inputs include the demand distribution by region, the manufacturing price, the effective income tax rate, and the net after tax profit margin. With this data and the marketing and distribution costs, projected income statements and solar array price estimates are produced.

The income statements are generated for a steady-state manufacturing year. The solar array prices (expressed in dollars per peak watt) are computed by dividing the annual array sales revenues by the demand. The price estimates include all manufacturing, marketing, and distribution expenses as well as a reasonable profit margin. The profit margin is a model parameter whose standard value is presented in Appendix A.

For comparisons with the JPL project price goals which are stated in 1975 dollars, a price level adjustment is made to deflate the prices to 1975 base year dollars.

Following is a more detailed description of the model parameters and equations.

B. Projected Income Statements

Exhibit IV-1 shows the income statement accounts for SELLCO, the hypothetical solar array sales and distribution company.

The costs and revenues on this statement are expressed in manufacturing year dollars.

The cost of goods sold is computed from the SAMICS manufacturing price and the demand distribution. These are specified as inputs by the model user.

Following are the financial model equations defining each of the income statement variables.

SELLCO

SOLAR ARRAY SALES AND DISTRIBUTION COMPANY

INCOME STATEMENT FOR THE YEAR ENDING _____

Sales:
- Household products
- Commercial products
- Central power stations

Total sales

Cost of goods sold:
- Household products
- Commercial products
- Central power stations

Total cost

Gross profit

Expenses:
- Distribution (Schedule A)
- Marketing (Schedule B)

Total expenses

Net profit before tax
Net income tax

Net profit after tax

Schedule A

Distribution expenses:
- Salaries and benefits
- Transportation
- Warehouse facilities:
  - Lease
  - Utilities
  - Other expenses

Total warehouse expenses

Inventory carrying charges

Total distribution expenses

Schedule B

Marketing expenses:
- Salaries and benefits
- Sales expenses
- Office facilities:
  - Lease
  - Utilities
  - Maintenance
  - Other expenses

Total office expenses

Advertising

Total marketing expenses

Revenue

REV_j = Total Annual Revenue in Region j (manufacturing year dollars)

$$= \left(\frac{1 - \tau}{1 - \tau - \rho} \right) [CGS_j + TDX_j + TMX_j]$$

where

CGS_j = Total Annual Cost of Goods Sold in Region j (manufacturing year dollars)

TDX_j = Total Annual Distribution Expense in Region j (manufacturing year dollars)

TMX_j = Total Annual Marketing Expense in Region j (manufacturing year dollars)

τ = Effective Income Tax Rate

ρ = Net Profit Margin Rate

Cost of Goods Sold

CGS_j = Total Annual Cost of Goods Sold in Region j (manufacturing year dollars)

$$= \sum_{i=1}^{3} d_{ij} * p * 10^6$$

where

d_{ij} = Annual Demand in Region j by all customers of type i (megawatts/year)

p = SAMICS Manufacturing Price for Solar Arrays (manufacturing year dollars/watt)

Gross Profit

GRO_j = Total Annual Gross Profit in Region j (manufacturing year dollars)

$$= REV_j - CGS_j$$

Distribution Expense

TDX_j = Total Annual Distribution Expense in Region j (manufacturing year dollars)

$$= IC_{kj} (Q_j^*) + DC_{kj}$$

where

DC_{kj} = Annual Distribution Cost in Region j for customers supplied directly from the factory in Region k (manufacturing year dollars)

$IC_{kj}(Q_j^*)$ = Annual Distribution Cost in Region j for customers supplied from a regional warehouse in Region j with transshipments from the factory in Region k (manufacturing year dollars)

Q_j^* = Optimal warehouse order quantity in Region j (megawatts/shipment)

Marketing Expense

TMX_j = Total Annual Marketing Expense in Region j (manufacturing year dollars)

$= DSC_j + ISC_j$

where

DSC_j = Total Annual Direct Sales Cost in Region j (manufacturing year dollars)

ISC_j = Total Annual Indirect Sales Cost in Region j (manufacturing year dollars)

Net Profit Before Tax

NPB_j = Net Profit Before Income Taxes in Region j (manufacturing year dollars)

$NPB_j = GRO_j - TDX_j - TMX_j$

Income Tax

TAX_j = Total Annual Income Tax Expense in Region j (manufacturing year dollars)

$TAX_j = \gamma * NPB_j$

where

γ = Effective Income Tax Rate

NPB_j = Net Profit Before Taxes in Region j

Net Profit After Tax

NPA = Net Profit After Income Tax in Region j (manufacturing year dollars)

$$= NPB_j - TAX_j$$

$$= \rho * REV_j$$

where

ρ = After Tax Profit Margin (Fraction of Total Revenues)

C. Solar Array Price Estimates

The solar array prices expressed in dollars per peak watt are computed separately for each customer product. The annual array sales revenues are divided by the demand.

The prices include the manufacturing cost, marketing expense, distribution expense, income tax, and profit.

SAP_{ij} = Solar Array Price for Customer Type i in Region j (1975 dollars/watt)

$$= \frac{REV_{ij}}{d_{ij}} * \Phi * 10^6$$

where

REV_{ij} = Total Annual Sales Revenues for product i in Region j (manufacturing year dollars)

d_{ij} = Total Annual Demand for product i in Region j

Φ = Deflator

$$= (1 + i)^{1976 - t_m}$$

t_m = Steady-State Manufacturing Year

i = Deflation Rate

The standard value for the deflation rate is presented in Appendix A.

V. TEST CASE

V. TEST CASE

A. Test Case Input Data

1. Supply Side Description

Production level = 500 MW/year

Manufacturing year = 1986

Manufacturing price = $.50 (1975 dollars)

= $.959/watt (1986 dollars)

Deflation multiplier = .5214

Solar array weight = 55 lb/array = 24.948 kg/array

Array dimensions = 14.6 ft^2 x 2 in thick = 1.36 m x 5.09 cm

Packaged in wood crates

Array volume (packaged) = 8 ft^3/array = .2265 m^3/array

Array performance = 160 watts/array

Efficiency = 11.8%

MODEL INPUT PARAMETERS

w = Solar array unit weight = 155,925 kg/mw

v = Solar array unit volume = 1415.805 m^3/mw

p = Solar array unit price = $.959/watt
1986 dollars

Factory location = Region II: Phoenix
Rocky Mountain
Region

t_{rm} = Manufacturing year = 1986

2. Demand Side Description

i	Customer Type	Average Order Quantity AOQ_i (MW)	Average Delivery Quantity q_i (MW)	Total Demand D_i (MW)	Number Of Orders Per Year	Number Of Deliveries Per Year
1	Residential Household	.01	.01	200 (40%)	20,000	20,000
2	Commercial Intermediate	.50	.50	100 (20%)	200	200
3	Public Utility Central Station	50.00	5.00	200 (40%)	4	40

Market Region j \ Customer Type i	d_{ij} Customer Demand Distribution (MW/YR)			Total Annual Demand (MW)
	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	
I West Coast	50.0	25.0	50.0	125.0
II Rocky Mountain	60.0	30.0	50.0	140.0
III North Central	10.0	5.0	0.0	15.0
IV Great Lakes	10.0	5.0	0.0	15.0
V North Eastern	20.0	10.0	50.0	80.0
VI South Eastern	10.0	5.0	0.0	15.0
VII South Central	40.0	20.0	50.0	110.0
Total	200.0	100.0	200.0	500.0

B. Marketing Model Results

1. Sales and Marketing Personnel Requirements

Market Region	Salesman	Direct Sales Support Staff	Indirect Sales Support Staff	Total Sales Personnel
I. West Coast	125	50	60	235
II. Rocky Mountain	150	58	72	280
III. North Central	25	18	11	44
IV. Great Lakes	25	8	11	44
V. North Eastern	50	25	26	101
VI. South Eastern	25	8	11	44
VII. South Central	100	41	49	190
All Regions	500 (53%)	198 (21%)	240 (26%)	938 (100%)

2. Sales and Marketing Expense Summary*

Market Region	Salaries And Expenses	Sales Expenses	Office Facilities Expenses	Advertising Expenses	Total Marketing Expenses
I. West Coast	$11,600,665	$1,144,634	$357,015	$1,246,700	$14,349,014
II. Rocky Mountain	13,585,452	1,350,541	380,565	1,486,450	16,803,008
III. North Central	1,996,253	206,411	69,525	239,750	2,511,939
IV. Great Lakes	2,285,647	236,333	66,169	239,750	2,827,899
V. North Eastern	4,603,451	426,200	168,483	527,450	5,725,584
VI. South Eastern	1,689,135	174,657	62,261	239,750	2,165,803
VII. South Central	8,011,289	781,629	255,357	1,006,950	10,055,225
All Regions	$43,771,892	$4,320,405	$1,359,375	$4,986,800	$54,438,472

*Expenses are expressed in 1986 (manufacturing year) dollars.

3. Solar Array Marketing Costs Per Watt

Market Region j \ Customer Type i	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Customers
I West Coast	$.1004	$.0174	$.0136	$.0599
II Rocky Mountain	.0994	.0708	.0135	.0626
III North Central	.0966	.0687	-	.0873
IV Great Lakes	.1086	.0776	-	.0983
V North Eastern	.0895	.0634	.0112	.0373
VI South Eastern	.0834	.0590	-	.0753
VII South Central	.0862	.0611	.0114	.0477
All Regions	$.0955	$.0679	$.0124	$.0568

*Expressed in 1975 $/watt.

C. Distribution Model Results

1. Distribution Network Configuration

Region	Factory-Warehouse Shipping Mode	Warehouse Size (Square Meters)	Average Inventory Level (MW)	Delivery Truck Fleet Size	Warehouse Personnel Level
I West Coast	Rail	353.95	.50	4	2
II Rocky Mountain	Direct Shipping	-	-	6	0
III North Central	Rail	70.79	.10	1	2
IV Great Lakes	Rail	70.79	.10	1	2
V North Eastern	Rail	141.58	.20	2	2
VI South Eastern	Rail	70.79	.10	1	2
VII South Central	Rail	283.16	.40	4	2
All Regions		991.06	1.40	19	12

2. Distribution Expense Summary*

Market Region j \ Customer Type i		Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Customers
I	West Coast	$1,296,406	$432,523	$865,050	$2,593,979
II	Rocky Mountain	127,947	63,974	106,623	298,544
III	North Central	665,811	283,217	0	949,028
IV	Great Lakes	852,920	375,104	0	1,228,024
V	North Eastern	2,145,472	974,241	4,871,208	7,990,921
VI	South Eastern	944,205	409,328	0	1,353,533
VII	South Central	2,127,709	891,423	2,228,558	5,247,690
	All Regions	$8,160,470	$3,429,810	$8,071,439	$1,966,719

*Expenses are expressed in 1986 (manufacturing year) dollars.

3. Solar Array Distribution Costs Per Watt

Market Region j \ Customer Type i	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Customers
I West Coast	$.0135	$.0090	$.0090	$.0108
II Rocky Mountain	.0011	.0011	.0011	.0011
III North Central	.0347	.0295	-	.0330
IV Great Lakes	.0445	.0391	-	.0427
V North Eastern	.0559	.0508	.0508	.0521
VI South Eastern	.0492	.0427	-	.0470
VII South Central	.0277	.0232	.0232	.0249
All Regions	$.0213	$.0179	$.0210	$.0205

*Expressed in 1986 (manufacturing year) dollars.

1. Sellco Projected Income Statements for the year ending December 31, 1986

Region	Total Sales Revenues	Cost Of Goods Sold	Gross Profit	Expenses	Net Profit Before Tax	Income Tax	Net Profit After Tax
I West Coast	191,545,190	119,875,000	71,670,190	16,942,993	54,727,197	27,910,870	26,816,327
II Rocky Mountain	211,906,173	134,260,000	77,646,173	17,101,552	60,544,621	30,877,757	29,666,864
III North Central	24,984,354	14,385,000	10,599,354	3,460,967	7,138,387	3,640,577	3,497,810
IV Great Lakes	25,817,292	14,385,000	11,432,292	4,055,923	7,376,369	3,761,948	3,614,421
V North Eastern	126,611,107	76,620,000	49,891,107	13,716,505	36,174,602	18,449,047	17,725,555
VI South Eastern	25,066,070	14,385,000	10,681,070	3,519,336	7,161,734	3,652,484	3,509,250
VII South Central	169,110,081	105,490,000	63,620,081	15,302,915	48,317,166	24,641,755	23,675,411
Overall Regions	775,040,267	479,500,000	295,540,267	74,100,191	221,440,076	112,934,438	108,505,638

2. Solar Array Price Estimates (1975 $/Watt)

Market Region j \ Customer Type i	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Customers
I West Coast	$.8595	$.8127	$.7316	$.7990
II Rocky Mountain	.8408	.8007	.7204	.7892
III North Central	.8839	.8376	-	.8685
IV Great Lakes	.9144	.8634	-	.8974
V North Eastern	.9036	.8599	.7869	.8252
VI South Eastern	.8857	.8424	-	.8713
VII South Central	.8596	.8180	.7486	.8016
All Regions	$.8636	$.8201	$.7469	$.8082

APPENDIX A

General Model Data

MARKETING AND DISTRIBUTION GEOGRAPHIC REGIONS

REGIONAL MARKETING AND DISTRIBUTION CENTERS

REGION	GEOGRAPHIC AREA	MARKETING AND DISTRIBUTION CENTER
I	West Coast	Los Angeles
II	Rocky Mountain	Phoenix
III	North Central	Omaha
IV	Great Lakes	Springfield
V	North Eastern	Syracuse
VI	South Eastern	Atlanta
VII	South Central	Dallas

INFLATION RATES

CODE	INFLATION CLASS	MEASURE	ANNUAL RATE
A	Raw materials	Crude materials price index	11%
B	Labor	Manufacturing labor	8%
C	Chemicals	Industrial chemicals	13%
D	Commodities	Producer finished goods	8%
E	Energy & Utilities	Electric power	12%
G	Land	Springfield Real Estate	4%
H	Facilities	Factory and commerical buildings	9%
I	Construction	Construction and contract labor	8%
J	Equipment	Machinery and equipment	7%
F	Resources	Natural resources	15%
T	Transportation	Transportation	7%

Sources: (a) Survey of current business statistics (1967 = 100) published by the U.S. Department of Commerce.

(b) Bureau of Labor Statistics.

(c) Springfield Illinois Chamber of Commerce.

REGIONAL COST INDICES

	Labor	Energy and Utilities	Facilities	Construction	Equipment
I West Coast	1.103	1.320	1.062	1.062	1.062
II Rocky Mountain	1.088	.820	.969	.969	.969
III North Central	1.014	.900	1.052	1.052	1.052
IV Great Lakes	1.161	.900	1.000	1.000	1.000
V North Eastern	.998	1.300	1.114	1.114	1.114
VI South Eastern	.858	.950	.938	.938	.938
VII South Central	.937	1.200	.927	.927	.927
National Average	1.000	1.000	1.041	1.041	1.041

Sources: Forbes, Business Week, Bureau of Labor Statistics, Data Resource Institute, National Bureau of Economic Research, Business School Professional, Engineering News Record, Census of Wholesale Trade, California Bureau of Labor Statistics, and Site Selection Handbook.

FINANCIAL PARAMETERS

τ = Effective income tax rate = 51%

λ = Financial leverage = $\frac{\text{Total Capital}}{\text{Total Equity}}$ = 1.20

r = Annual return on equity = 21%

i = Deflation Rate = 6%

ρ = After Tax Profit Margin = 14%

APPENDIX B

MARKETING MODEL DATA

SALESMAN PRODUCTIVITY AND SUPPORT INDICES

Average Order Quantity (MW) ACQ	Megawatt Sales Per Salesman (MW/YR) MWS	Salesman Support Index SSI
.001	.50	.100
.010	.51	.101
.100	.59	.109
1.000	1.45	.190
10.000	10.00	1.000
100.000	95.51	5.000

DIRECT SALES PERSONNEL COMPENSATION RATES

Salesman

Index i	Description	Annual Compensation* CS_i
1	Salesman, Household Products	$18,060
2	Salesman, Intermediate Commercial Products	$24,000
3	Salesman, Central Power Stations	$31,920

Direct Sales Support Personnel

Index k	Description	Requirement Coefficient RC_k	Annual Compensation* AC_k
1	Field Engineer	2.0	$26,400
2	Commercial Artist	.1	$12,320
3	Market Research Analyst	.4	$25,200
4	Technical Illustrator	.2	$18,900
5	Technical Writer	.2	$18,900
6	Advertising Salesman	.1	$17,500

*Compensation rates include all wages and benefits, are expressed in 1977 dollars per year, and based on nationwide averages.

INDIRECT SALES SUPPORT STAFF RELATIONSHIPS*

Indirect Staff	Required By Staff	D_i	I_i
Secretary I (Lower Management)	Salesman, Household Products	9	1
	Salesman, Intermediate Commercial	6	1
	Salesman, Central Power Stations	4	1
	Market Research Analyst	4	1
	Salesman, Advertising	4	1
Secretary II (Middle Management)	Manager, Sales Engineering	2	1
	Manager, Sales	2	1
	Manager, Advertising	2	1
	Manager, Market Research	2	1
Secretary III (Upper Management)	Regional Vice President, Sales and Marketing	1	1
Manager, Advertising	Commercial Artist	9	1
	Salesman, Advertising	6	1
Manager, Marketing Research	Marketing Research Analyst	6	1
Manager, Sales	Salesman, Household Products	9	1
	Salesman, Intermediate Commercial	6	1
	Salesman, Central Station	4	1
Manager, Sales Engineering	Field Engineer	9	1
	Technical Writer	9	1
	Technical Illustrator	9	1
Vice President, Sales and Marketing	Manager, Sales	4	1
	Manager, Sales Engineering	4	1
	Manager, Advertising	4	1
	Manager, Marketing Research	4	1

*I_i is the number of "Indirect Staff" for D_i of the "Required by Staff". For example, one Secretary I (Lower Management) is required for every nine salesmen of household products.

INDIRECT SALES PERSONNEL COMPENSATION RATES

Job Title	Annual Compensation (Wages + Benefits) (1977 $/Year)
Vice President, Sales and Marketing	$59,800
Manager, Sales Engineering	$38,400
Manager, Sales	$38,400
Manager, Advertising	$38,400
Manager, Marketing Research	$38,400
Market Research Analyst	$25,200
Technical Illustrator	$18,900
Commercial Artist	$12,320
Technical Writer	$18,900
Field Engineer	$26,400
Salesman, Advertising	$17,500
Salesman, Household Products	$18,060
Salesman, Intermediate Commercial Products	$24,000
Salesman, Central Power Stations	$31,920
Secretary I (Lower Management)	$13,650
Secretary II (Middle Management)	$14,560
Secretary III (Upper Management)	$15,890

SALES OFFICE FACILITIES COST PARAMETERS

SPP	=	Amount of office space per person (square meters/person)	= 12.45
γ_o	=	Office Facilities Lease Rate (% of capital cost)	= 12.6%
ρ_o	=	Office Utilities Cost Rate (1977 $/square meter)	= $1.20
m	=	Office Maintenance Cost Rate (% of capital cost)	= 1.0%
β	=	Property Tax Rate (% of capital cost)	= 4.0%
$\sqrt{}$	=	Insurance Rate (% of capital cost)	= 1.0%

SALES OFFICE CAPITAL COST FUNCTION

Sales Office Size (Square Meters) S	Total Office Capital Cost (1977 $) $K_o(S)$
$0 < S \leq 185$	$K_o(S) = 366.49*S$
$185 < S \leq 278$	$K_o(S) = 28412.90 + 212.90*S$
$278 < S \leq 372$	$K_o(S) = 5382.98 + 295.74*S$
$372 < S \leq 557$	$K_o(S) = 21696.22 + 251.89*S$
$557 < S \leq 1115$	$K_o(S) = 3284.95 + 284.95*S$
$1115 < S$	$K_o(S) = 24781.24 + 265.67*S$

SALES AND ADVERTISING EXPENSE PARAMETERS

Customer/Product Type i	Average Order Quality Range AOQ_i (Megawatts/Order)	Sales Expense Rate SAE_i	Advertising Cost Rate ADE_i
1. Small Household Products	0.00- .05	20%	2.0%
2. Intermediate Commercial Products	0.05-1.00	25%	1.0%
3. Large Central Power Stations	1.00-500	30%	0.1%

APPENDIX C

DISTRIBUTION MODEL DATA

TABLE C-1

INTERREGIONAL SHIPPING DISTANCES
(Kilometers)

Origin Region \ Destination Region	I West Coast Los Angeles	II Rocky Mountain Phoenix	III North Central Omaha	IV Great Lakes Springfield	V North Eastern Syracuse	VI South Eastern Atlanta	VII South Central Dallas
I West Coast Los Angeles	—	640	2788	3057	4344	3540	2293
II Rocky Mountain Phoenix	640	—	2100	2782	3595	3036	1652
III North Central Omaha	2788	2100	—	644	1770	1609	1064
IV Great Lakes Springfield	3057	2782	644	—	1287	965	1207
V North Eastern Syracuse	4344	3595	1770	1287	—	1529	2414
VI South Eastern Atlanta	3540	3036	1609	965	1529	—	1287
VII South Central Dallas	2293	1652	1064	1207	2414	1287	—

TABLE C-2

INTERREGIONAL TRANSPORTATION COST FUNCTION

Weight Class (Kilograms)	Transportation Mode	Freight Charge Rate (1977 $ Per 100 Kilograms)
Less than 225	Truck	20.8400 + .01845*S
225 to 450	Truck	16.3100 + .01986*S
450 to 900	Truck	13.3400 + .01951*S
900 to 2250	Truck	11.4800 + .01774*S
2250 to 4500	Truck	7.0790 + .01845*S
4500 to 10800	Truck	5.9020 + .01880*S
10800 to 18000	Truck	5.4320 + .01135*S
18000 to 36000	Rail	0.7440 + .00918*S
More than 36000	Rail	0.0192 + .00940*S

Where S = Shipping distance in kilometers

*Rail rates have been adjusted to include delivery to and from the train depot and to reflect differences between rail distance and road distance. Thus, the freight charges represent door-to-door transportation costs.

TABLE C-3

INTRAREGIONAL TRANSPORTATION COSTS*

Following is a list of delivery cost parameters for a medium duty conventional truck. A medium duty truck with a capacity of 80,000 kg was selected for the base case since it is capable of carrying a load of 500 kw of solar collectors. This wouuld correspond approximately to 50 residential customers or to one commercial customer.

- Vehicle Distance Capacity

  Assuming 250 days per year and 320 kilometers per day
  MC = 75,000 kilometers/vehicle-year

- Vehicle Load Capacity

  WC = 80,000 kilograms/delivery

- Annual Fixed Cost Per Vehicle

Purchase cost, net $12,500	
Capital recovery (5 year life, 20% salvage)	$2,000
Annual interest (@ 10.5%, λ = 1.2)	219
Annual return on equity (21%, λ = 1.2)	2,188
Tax on equity	2,188
Where λ = Financial Leverage = Total Capital / Equity Capital	$6,595

Present value of tax savings $484	
Assuming accelerated depreciation at 18.37%	
Annual amortization of tax saving	(156)
Net capital cost	$6,439
Insurance	2,000
Driver's wages and benefits	15,600

FC = Annual Fixed Cost per Vehicle = $24,039

- Variable Operating Cost Per Vehicle Kilometer

Gas	$.075/kilometer
Oil and maintenance	.020/kilometer

VC = Variable Operating Cost per vehicle kilometer = $.095/kilometer

*All costs are expressed in 1977 dollars per year.

WAREHOUSE COST PARAMETERS STANDARD VALUES

α = Warehouse space utilization factor = .25

K_b = Building capital cost function (Table C-4)

K_e = Equipment capital cost function (Table C-5)

P = Personnel cost function (Table C-6)

m = Maintenance cost rate = 1%/year
(% of capital cost/year)

ρ_w = Warehouse utilities cost rate = $1.20/square meter/year

β = Property tax rate = 4%/year
(% of capital cost/year)

ν = Insurance rate = 1%/year
(% of capital cost/year)

γ_e = Equipment lease rate = .25/year
(fraction of capital cost/year)

γ_b = Building lease rate = .126/year
(fraction of capital cost/year)

σ = Inventory carrying charge rate = 37.75%/year

- Warehouse Space Utilization Factor

The warehouse space utilization factor is used to compute the total amount of warehouse space required, based on the maximum inventory quantity and the physical volume of the solar array units.

The multiplier includes the stacking height and allows for circulation and office areas. The standard value is based on the following assumptions:

- The inventory is stacked on pallets five meters high.
- A single factory shipment occupies 80% of the total warehouse area. This is the maximum inventory level with no space for safety stock. The remaining 20% of the warehouse is occupied by aisles, office areas, and restrooms.

α = Warehouse space utilization factor

$$= \left(\frac{100\%}{80\%}\right)\left(\frac{1 \text{ square meter of warehouse floor}}{5 \text{ cubic meters of product}}\right)$$

$$= .25/\text{meter}$$

- Building Capital Cost Function

The capital cost for construction of a warehouse depends on the size and location of the facility. A TB&A engineering cost analysis yielded the following average 1977 warehouse contruction costs for Springfield, Illinois.

Warehouse Size (Square Meters)	Average Construction Cost* ($/square meter)
250	245.96
1000	233.58
2500	221.21
25000	181.92

*Expressed in 1977 dollars for Springfield, Illinois in Region IV.

These point estimates were used to develop a piecewise linear function to compute building capital costs. The relationships, tabulated on the following page were adjusted to include land costs. Since land costs vary considerably from one location to another and do not represent a major portion of the total cost, a simplifying assumption was made. The cost of land is taken to be 10% of the total warehouse cost. This value may actually range from 5% to 18% depending on the location.

To account for regional differences in construction costs, the cost relations should be adjusted using the regional construction cost index.

TABLE C-4

BUILDING CAPITAL COST FUNCTION

Warehouse Size F (Square Meters)	Total Land And Building Cost (1977 $)
$0 < F \leq 250$	$K_b(F) = 0.00 + 245.96 * F$
$250 < F \leq 1000$	$K_b(F) = 4126.70 + 229.45 * F$
$1000 < F \leq 2500$	$K_b(F) = 20616.75 + 212.96 * F$
$2500 < F$	$K_b(F) = 109140.00 + 177.55 * F$

- Equipment Capital Cost Function

Warehouse equipment consists of forktrucks, conveyors, lifts, carts, pallets, and other materials handling equipment. The cost of items are approximated as a function of the size of the warehouse. The following table gives the approximated capital cost relationships. The function yields economies of scale (that is, decreasing costs per square meter) for larger warehouses. The rationale for this phenomena is that larger warehouses are able to substitute capital for labor making automated equipment more economically.

TABLE C-5

Warehouse Size F (Square Meters)	Equipment Capital Cost (1977 $)
$0 < F \leq 1000$	$K_e(F) = 26 * F$
$1000 < F \leq 2500$	$K_e(F) = 5000 + 21 * F$
$2500 < F$	$K_e(F) = 10000 + 19 * F$

- Warehouse Personnel Cost

The number of warehouse personnel required per square meter of space varies with the size of the warehouse. This reflects the assumption that larger warehouses will operate more efficiently and hence require fewer people per square meter. The following tables indicate the type of personnel and the quantity required for different warehouse sizes.

Personnel Description	Percent Of Total Personnel	Annual Cost*
Warehouse Supervisor	10%	$21,450
Forklift Operator	50%	11,000
Inventory Clerk	20%	13,510
Material Handler	20%	16,800
Total weighted average	100%	13,707

*The annual cost for personnel includes both wages and benefits and is based on a nationwide survey. The costs should be multiplied by the appropriate labor cost index to reflect regional conditions.

Warehouse Size (Square Meters)	Total Personnel	Personnel Per 1000 Square Meters
1	2	
2000	2	1.00
5000	4	.80
10000	7	.70
15000	10	.67
25000	15	.60

The annual cost for personnel includes both wages and benefits based on a nationwide survey. The amounts are expressed in 1977 dollars and should be multiplied by the appropriate labor cost index to reflect regional conditions. The following table presents equations (corresponding to the above table) for computing the annual personnel cost as a function of the warehouse size.

TABLE C-6

PERSONNEL COST FUNCTION

Warehouse Size	Annual Personnel Cost
$0 < F \leq 2000$	$P(F) = 27{,}414$
$2000 < F \leq 5000$	$P(F) = 9{,}138 + 9.1380*F$
$5000 < F \leq 15000$	$P(F) = 13{,}707 + 8.2242*F$
$15000 < F$	$P(F) = 34{,}267.50 + 6.8535*F$

F = Warehouse size (square meters)

P(F) = Annual warehouse personnel cost (1977 $/year)

- Maintenance Cost Rate

Maintenance costs for a warehouse can be approximated as a percent of the capital cost of the building and equipment.

m = Maintenance Cost Rate (% of capital cost/year)
= 1%/year

- Utility Cost Rate

For a warehouse the major utility expense is the electric power cost. Hence, only electricity costs are computed directly. Other utility expenses (telephone, water, sewage disposal, fuel oil, etc.) are assumed to be a multiple of the total electricity cost. Since utility expenses are a small portion of the total warehouse operating cost, this simplifying assumption will not affect the end results significantly. Following are the assumptions for computing the annual utility cost rate per square meter of warehouse space:

Electric Power Cost:

$$\text{Capacity} = .5 \frac{\text{watts}}{\text{square foot}} \quad \frac{1 \text{ square foot}}{.0929 \text{ square meters}}$$

$$= 5.38 \text{ watts/square meter}$$

$$\text{Demand} = 40\% \left(365 \frac{\text{days}}{\text{year}}\right) \left(24 \frac{\text{hours}}{\text{day}}\right)$$

$$= 3504 \text{ hours/year}$$

Rate = $.0319/kilowatt-hour (in 1977 dollars)

$$\text{Cost} = 5.38 \left(\frac{3504}{1000}\right)^{*} (\$.0319)$$

$$= \$.60/\text{square meter}$$

Total Utility Cost:

ρ_w = Warehouse Utility Cost Rate

ρ_w = 2 (electric power cost)

= $1.20/square meter/year

The electricity cost rate is from Springfield, Illinois in Region III in 1977. The utility cost index must be used to obtain the cost for other regions, and the utility inflation rate must be used to adjust for other years.

- Insurance Rate

The cost of insurance for a warehouse is assumed to be 1% of the original book value of the warehouse building and equipment.

ν = Insurance Rate (% of capital cost/year)
= 1%/year

- Property Tax Rate

Property taxes are assumed to be 4% of the market value of the warehouse building and equipment.

β = Property Tax Rate (% of capital cost/year)
= 4%/year

The annual leasing cost for both the warehouse building and equipment is computed to yield the lessor a gross return of 12.5% on the capital investment. The economic lives are assumed to be five years for equipment and 40 years for buildings.

- Equipment Lease Rate

$$\gamma_e = \frac{(1-s)}{\frac{1-(1+i)^n}{i}}$$

where

s = Salvage Value Fraction = .10; that is (1 - s) = Effective replacement cost (that is, purchase price minus salvage value) fraction of the purchase price

n = Economic Life = 5 years

i = Lessor's Rate of Return = 12.5%

γ_e = .25

- Building Lease Rate

$$= \frac{(1-s)}{\frac{1-(1+i)^n}{i}}$$

where

s = 0

n = 40 years

i = 12.5%

γ_b = .126

- Inventory Carrying Charge Rate

Inventory carrying charges represent the cost of capital tied up in inventories. The model computes this cost by multiplying the average inventory value by the carrying charge rate, δ. The standard value of δ is computed as follows:

δ = Inventory Carrying Charge Rate

$$= i\left(\frac{\lambda-1}{\lambda}\right) + r\left(\frac{1}{\lambda}\right)\left(\frac{1}{1-\tau}\right) + U$$

where

i = Cost of debt capital = .105

λ = Leverage ratio = $\frac{\text{Total capital}}{\text{Total equity}}$ = 1.2

r = Rate of return on equity = .21

τ = Effective income Tax Rate = .51

U = Inventory Insurance Rate = .01

The values listed above yield δ = 37.75%

APPENDIX D

TEST CASE CALCULATIONS

MARKETING MODEL CALCULATIONS

INDEX

MARKETING EXPENSE SUMMARY*
(For All Products by Region)

Market Region	Salaries And Benefits	Sales Expenses	Office Facilities Expenses	Advertising Expenses	Total Marketing Expenses
I West Coast	$11,600,665	$1,144,634	$357,015	$1,246,700	$14,349,014
II Rocky Mountain	13,585,452	1,350,541	380,565	1,486,450	16,803,008
III North Central	1,996,253	206,411	69,525	239,750	2,511,939
IV Great Lakes	2,285,647	236,333	66,169	239,750	2,827,899
V North Eastern	4,603,451	426,200	168,483	527,450	5,725,584
VI South Eastern	1,689,135	174,657	62,261	239,750	2,165,803
VII South Central	8,011,289	781,629	255,357	1,006,950	10,055,225
All Regions	$43,771,892	$4,320,405	$1,359,375	$4,986,800	$54,438,472

*Costs are expressed in 1986 (manufacturing year) dollars.

SALARIES AND BENEFITS*
(By Product and Region)

Market Region	Residential Household Products	Intermediate Commercial Products	Central Power Stations	Total Salaries and Benefits
I West Coast	$7,667,142	$2,765,895	$1,167,628	$11,600,665
II Rocky Mountain	9,127,576	3,293,462	1,164,414	13,585,452
III North Central	1,466,447	529,806	0	1,996,253
IV Great Lakes	1,679,036	606,611	0	2,285,647
V North Eastern	2,683,643	966,761	953,047	4,063,451
VI South Eastern	1,240,838	448,297	0	1,689,135
VII South Central	5,169,816	1,864,431	977,042	8,011,289
All Regions	$29,034,498	$10,475,263	$4,262,131	$43,771,892

*Expressed in 1986 (manufacturing year) dollars and adjusted by the regional labor cost indices.

SALES EXPENSES*
(By Product and Region)

Market Region	Residential Household Products	Intermediate Commercial Products	Central Power Stations	Total Advertising Expense
I West Coast	$783,094	$339,547	$21,993	$1,144,634
II Rocky Mountain	926,936	401,912	21,693	1,350,541
III North Central	143,984	62,427	0	206,411
IV Great Lakes	164,857	71,476	0	236,333
V North Eastern	283,417	122,885	19,898	426,200
VI South Eastern	121,833	52,824	0	174,657
VII South Central	532,189	230,757	18,683	781,629
All Regions	$2,956,310	$1,281,828	$82,267	$4,320,405

*Expressed in 1986(manufacturing year)dollars. Sales expenses include office supplies, travel and entertainment, and communication.

OFFICE FACILITIES EXPENSES
(By Product and Region)

Market	Residential Household Products	Intermediate Commercial Products	Central Power Stations	Total Office Facilities Expense
I West Coast	$214,178	$80,364	$62,473	$357,015
II Rocky Mountain	235,165	88,238	57,162	380,565
III North Central	50,556	18,969	0	69,525
IV Great Lakes	48,116	18,053	0	66,169
V North Eastern	81,185	30,461	56,837	168,483
VI South Eastern	45,274	16,987	0	62,261
VII South Central	146,770	55,072	53,515	255,357
All Regions	$821,244	$308,144	$229,987	$1,359,375

*Expressed in 1986 (manufacturing year) dollars and adjusted by the regional facilities cost indices.

ADVERTISING EXPENSES*
(By Product and Region)

Market Region	Residential Household Products	Intermediate Commercial Products	Central Power Stations	Total Advertising Expense
I West Coast	$959,000	$239,750	$47,950	$1,246,700
II Rocky Mountain	1,150,800	287,700	47,950	1,486,450
III North Central	191,800	47,950	0	239,750
IV Great Lakes	191,800	47,950	0	239,750
V North Eastern	383,600	95,900	47,950	527,450
VI South Eastern	191,800	47,950	0	239,750
VII South Central	767,200	191,800	47,950	1,006,950
All Regions	$3,836,000	$959,000	$191,800	$4,986,800

*Expressed in 1986 (manufacturing year) dollars.

TOTAL MARKETING EXPENSES
(By Product and Region)

Market Region	Residential Household Products	Intermediate Commercial Products	Central Power Stations	Total Advertising Expense
I West Coast	$9,263,414	$3,425,556	$1,300,044	$14,349,014
II Rocky Mountain	11,440,477	4,071,312	1,291,219	16,803,008
III North Central	1,852,787	659,152	0	2,511,939
IV Great Lakes	2,083,809	744,090	0	2,827,899
V North Eastern	3,431,845	1,216,007	1,077,732	5,725,584
VI South Eastern	1,599,745	566,058	0	2,165,803
VII South Central	6,615,975	2,342,060	1,097,190	10,055,225
All Regions	$36,648,052	$13,024,235	$4,766,185	$54,438,472

MARKETING EXPENSE SUMMARY*
(For Household Products by Region)

	Salaries And Benefits	Sales Expenses	Office Facilities Expense	Advertising Expenses	Total Marketing Expenses
I West Coast	$7,667,142	$783,094	$214,178	$959,000	$9,623,414
II Rocky Mountain	9,127,576	926,936	235,165	1,150,800	11,440,477
III North Central	1,466,447	143,984	50,556	191,800	1,852,787
IV Great Lakes	1,679,036	164,857	48,116	191,800	2,083,809
V North Eastern	2,683,643	283,417	81,185	383,600	3,431,845
VI South Eastern	1,240,838	121,833	45,274	191,800	1,599,745
VII South Central	5,169,816	532,189	146,770	767,200	6,615,975
All Regions	$29,034,498	$2,956,310	$821,244	$3,836,000	$36,648,052

*Expressed in 1986 (manufacturing year) dollars.

MARKETING EXPENSE SUMMARY*
(For Intermediate Commercial Products by Region)

Market Region	Salaries And Benefits	Sales Expenses	Office Facilities Expense	Advertising Expenses	Total Marketing Expenses
I West Coast	$2,765,895	$339,547	$80,364	$239,750	$3,425,556
II Rocky Mountain	3,293,462	401,912	88,238	287,700	4,071,312
III North Central	529,806	62,427	18,969	47,950	659,152
IV Great Lakes	606,611	71,476	18,053	47,950	744,090
V North Eastern	966,761	122,885	30,461	95,900	1,216,007
VI South Eastern	448,297	52,824	16,987	47,950	566,058
VII South Central	1,864,431	230,757	55,072	191,800	2,342,060
All Regions	$10,475,263	$1,281,828	$308,144	$959,000	$13,024,235

*Expressed in 1986 (manufacturing year) dollars.

MARKETING EXPENSE SUMMARY*
(For Central Power Station Products By Region)

Market Region	Salaries And Benefits	Sales Expenses	Office Facilities Expenses	Advertising Expenses	Total Marketing Expenses
I West Coast	$1,167,628	$21,993	$62,473	$47,950	$1,300,044
II Rocky Mountain	1,164,414	21,693	57,162	47,950	1,291,219
III North Central	0	0	0	0	0
IV Great Lakes	0	0	0	0	0
V North Eastern	953,047	19,898	56,837	47,950	1,077,732
VI South Eastern	0	0	0	0	0
VII South Central	977,042	18,683	53,515	47,950	1,097,190
All Regions	$4,262,131	$82,267	$229,987	$191,800	$4,766,185

*Expressed in 1986 (manufacturing year) dollars.

SALES AND MARKETING PERSONNEL COST SUMMARY*
(By Personnel Category and Region)

Market Region		Salesman	Direct Sales Support Staff	Indirect Sales Support Staff	Total Sales Personnel
I	West Coast	$5,346,964	$2,674,567	$3,579,134	$11,600,665
II	Rocky Mountain	6,314,644	3,073,567	4,197,241	13,585,452
III	North Central	969,632	405,687	620,934	1,996,253
IV	Great Lakes	1,110,200	464,500	710,947	2,285,647
V	North Eastern	1,974,954	1,222,062	1,406,435	4,603,451
VI	South Eastern	820,458	343,274	525,403	1,689,135
VII	South Central	3,646,254	1,897,294	2,467,741	8,011,289
	All Regions	$20,183,106	$10,080,951	$13,507,835	$43,771,892

*Costs are expressed in 1986 (manufacturing year) dollars and adjusted by the regional labor cost indices. Compensation includes both salaries and benefits.

SALESMAN COSTS*
(By Product and Region)

Market Region / Personnel Description (Base Compensation) 1977 Dollars	West Coast I	Rocky Mountain II	North Central III	Great Lakes IV	North Eastern V	South Eastern VI	South Central VII
Salesman, Household Products ($18,060)	$3,915,472	$4,634,686	$719,922	$824,290	$1,417,088	$609,165	$2,660,947
Salesman, Intermediate Commercial ($24,000)	1,358,184	1,607,646	249,710	285,910	491,537	211,293	923,032
Salesman, Central Power Stations ($31,920)	73,308	72,312	0	0	66,329	0	62,275
Total Salesman Cost	$5,346,964	$6,314,644	$969,632	$1,110,200	$1,974,954	$820,458	$3,646,254

*Expressed in 1986(manufacturing year)dollars/year and adjusted by the regional labor cost indices base compensation includes both salary and benefits.

DIRECT SALES SUPPORT PERSONNEL COSTS*

Personnel Description (Base Compensation) 1977 Dollars \ Market Region	West Coast I	Rocky Mountain II	North Central III	Great Lakes IV	North Eastern V	South Eastern VI	South Central VII
Field Engineer ($26,400)	$1,923,414	$2,210,239	$291,751	$324,046	$878,820	$246,865	$1,364,347
Commercial Artist ($12,320)	44,876	51,580	6,817	7,806	20,498	5,769	31,844
Market Research Analyst ($25,200)	367,163	421,966	55,676	63,748	167,764	47,112	260,456
Technical Illustrator ($18,900)	137,685	158,257	20,880	23,906	62,931	17,667	97,707
Technical Writer ($18,900)	137,685	158,257	20,880	23,906	62,931	17,667	97,707
Advertising Salesman ($17,500)	63,744	73,268	9,683	11,088	29,118	8,194	45,233
Total Direct Sales Support Personnel Cost	$2,674,567	$3,073,567	$405,687	$464,500	$1,222,062	$343,274	$1,897,294

*Expressed in 1986(manufacturing year)dollars/year and adjusted by the regional labor cost indices base compensation includes both salary and benefits.

INDIRECT SALES SUPPORT PERSONNEL COSTS*

Personnel Description (Base Compensation) 1977 Dollars / Market Region	West Coast I	Rocky Mountain II	North Central III	Great Lakes IV	North Eastern V	South Eastern VI	South Central VII
Regional Vice President ($59,800)	$706,204	$827,702	$122,063	$139,758	$278,927	$103,285	$487,353
Manager, Advertising ($38,400)	38,439	44,682	5,915	6,773	17,773	5,006	27,548
Manager, Market Research ($38,400)	93,220	107,153	14,167	16,220	42,595	11,986	66,171
Manager, Sales ($38,400)	1,309,224	1,545,313	236,700	271,015	485,772	200,284	893,461
Manager, Sales Engineering ($38,400)	372,964	428,693	56,666	64,880	170,377	47,948	264,686
Secretary I (Lower Management) ($13,650)	527,539	620,739	93,547	107,109	201,052	79,155	361,702
Secretary II (Middle Management) ($14,560)	343,891	403,023	59,438	68,056	135,824	50,295	237,320
Secretary III (Upper Management) ($15,890)	187,653	219,936	32,434	37,136	74,115	27,444	129,500
Total Indirect Sales Support Personnel Costs	$3,579,134	$4,197,241	$620,934	$710,947	$1,406,435	$525,403	$2,467,741

*Expressed in 1986 (manufacturing year) dollars/year and adjusted by the regional labor cost indices. Base compensation includes both salary and benefits.

SALES AND MARKETING PERSONNEL SUMMARY
(By Personnel Category and Region)

Market Region	Salesman	Direct Sales Support Staff	Indirect Sales Support Staff	Total Sales Personnel
I West Coast	125.036	49.563	60.375	234.974
II Rocky Mountain	149.834	57.744	71.818	279.396
III North Central	24.799	8.178	11.346	44.413
IV Great Lakes	24.799	8.178	11.346	44.413
V North Eastern	50.638	25.029	26.088	101.755
VI South Eastern	24.799	8.178	11.346	44.413
VII South Central	100.237	41.389	48.956	190.582
All Regions	500.142 (53%)	198.259 (21%)	241.545 (26%)	939.946 (100%)

SALES FORCE SIZE
(By Product and Region)

Market Region j \ Customer Type i	Total Number Of Salesmen Required In Region j For Customer Type i (SR_{ij})			
	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Customers
I West Coast	98.328	25.666	1.0415	125.036
II Rocky Mountain	117.994	30.799	1.0415	149.834
III North Central	19.666	5.133	0.0000	24.799
IV Great Lakes	19.666	5.133	0.0000	24.799
V North Eastern	39.331	10.266	1.0415	50.638
VI South Eastern	19.666	5.133	0.0000	24.799
VII South Central	78.662	20.533	1.0415	100.237
All Regions	393.313	102.663	4.1664	500.142

SALESMAN PRODUCTIVITY AND SUPPORT INDICES

Customer Type i	Number Of Customers All Regions Per Year	Average Order Quantity AOQ_i (MW)	Megawatt Sales Per Salesman MWS_i (MW/YR)	Salesman Support Index SSI_i	Total Salesmen For Customer i In All Regions
1 Residential Household	20,000	.01	50.850	.1008	393.313
2 Commercial Intermediate	200	.50	1.948	.1449	102.663
3 Public Utility Central Station	4	50.00	.960	48.0040	4.166
All Regions	20,204	.025	40.408	.997	500.142

DIRECT SALES SUPPORT PERSONNEL REQUIREMENTS
(By Personnel Type and Region)

Market Region j \ Personnel Type k	Field Engineer 1	Commercial Artist 2	Market Research Analyst 3	Technical Illustrator 4	Technical Writer 5	Advertising Salesman 6	Total Direct Sales Support Personnel In Region j TSPj
I West Coast	33.043	1.652	6.608	3.304	3.304	1.652	49.563
II Rocky Mountain	38.495	1.925	7.699	3.850	3.850	1.925	57.744
III North Central	5.452	.273	1.090	.545	.545	.273	8.178
IV Great Lakes	5.452	.273	1.090	.545	.545	.273	8.178
V North Eastern	16.686	.834	3.337	1.669	1.669	.834	25.029
VI South Eastern	5.452	.273	1.090	.545	.545	.273	8.178
VII South Central	27.591	1.380	5.518	2.760	2.760	1.380	41.389
All Regions	132.171	6.610	26.432	13.218	13.218	6.610	198.259

INDIRECT SALES SUPPORT PERSONNEL REQUIREMENTS
(By Personnel Type and Region)

Personnel Description \ Market Region j	West Coast I	Rocky Mountain II	North Central III	Great Lakes IV	North Eastern V	South Eastern VI	South Central VII	All Regions
Regional Vice President	5.356	6.364	1.007	1.007	2.338	1.007	4.351	21.430
Manager, Advertising	.454	.535	.076	.076	.232	.076	.383	1.832
Manager, Market Research	1.101	1.283	.182	.182	.556	.182	.920	4.406
Manager, Sales	15.463	18.503	3.041	3.041	6.341	3.041	12.422	61.852
Manager, Sales Engineering	4.405	5.133	.728	.728	2.224	.728	3.680	17.626
Scretary I (Lower Mgmt.)	17.528	20.909	3.381	3.381	7.383	3.381	14.147	70.110
Secretary II (Middle Mgmt.)	10.712	12.727	2.014	2.014	4.676	2.014	8.702	42.859
Secretary III (Upper Mgmt.)	5.356	6.364	1.007	1.007	2.338	1.007	4.351	21.430
Total Indirect Sales Support Personnel	60.375	71.818	11.436	11.436	26.088	11.436	48.956	241.545

SALES AND MARKETING OFFICE FACILITIES EXPENSES

	Facilities Cost Index	Utilities Cost Index	Total Sales Personnel	Sales Office Size (Square Meters)	Facilities Capital Value (1986 $)	Office Lease Expense (1986 $)	Office Utilities Expense (1986 $)	Office Maintenance Expense (1986 $)	Other Office Expenses (1986 $)	Total Office Expenses (1986 $)
I West Coast	1.062	1.320	235	2,926	$1,850,836	$233,118	$12,853	$18,502	$92,542	$357,015
II Rocky Mountain	0.969	0.820	279	3,475	1,995,073	251,379	9,481	19,951	99,754	380,565
III North Central	1.052	0.900	44	548	364,963	45,986	1,642	3,649	18,248	69,525
IV Great Lakes	1.000	0.900	44	548	346,923	43,712	1,642	3,469	17,346	66,169
V North Eastern	1.114	1.300	102	1,270	876,287	110,412	5,493	8,764	43,814	168,483
VI South Eastern	0.938	0.950	44	548	325,415	41,003	1,733	3,254	16,271	62,261
VII South Central	.927	1.200	191	2,378	1,321,836	166,552	9,495	13,218	66,092	255,357
All Regions	1.041	1.000	939	11,693	$7,081,333	$892,162	$42,339	$70,807	$354,067	$1,359,375

DISTRIBUTION MODEL CALCULATIONS

INDEX

TOTAL ANNUAL DISTRIBUTION COST CALCULATIONS
FROM THE FACTORY IN REGION k = II ROCKY MOUNTAIN
TO CUSTOMERS IN REGION j = I WEST COAST

Customer Type i	Shipping Indicator X_{ij}	Annual Direct Shipping Cost (1986 $) DC_{kj}	Annual Distribution Costs For Transshipments (1986 $) IC_{kj}	Total Annual Distribution Cost Region j (1986 $) TC_{kj}
1	1	0.00		
2	1	0.00		
3	1	0.00		
Total		0.00	2,856,572.00	2,856,572.00
1	0	3,272,805.70	0.00	3,272,805.70
2	1	0.00		
3	1	0.00		
Total		3,272,805.70	1,627,026.00	4,899,831.70
1	1	.00		
2	0	432,523.67	0.00	432,523.67
3	1	.00		
Total		432,523.67	2,333,564.00	2,766,087.67
1	1	0.00		
2	1	0.00		
3	0	865,049.73	0.00	865,049.73
Total		865,049.73	1,817,623.00	2,682,672.73
1	0	3,272,805.70	0.00	3,272,805.70
2	0	432,523.67	0.00	432,523.67
3	1	0.00	1,105,809.00	1,105,809.00
Total		3,705,329.30	1,105,809.00	4,811,138.30
1	0	3,272,805.70	0.00	3,272,805.70
2	1	0.00	587,513.00	587,513.00
3	0	865,049.73	0.00	865,049.73
Total		4,137,855.4	587,513.00	4,725,368.40
1	1	0.00	1,296,406.00	1,296,406.00
2	0	432,523.67	0.00	432,523.67
3	0	865,049.73	0.00	865,049.73
Total		1,297,573.40	1,296,406.00	2,593,979.40*
1	0	3,272,805.70	0.00	3,272,805.70
2	0	432,523.67	0.00	432,523.67
3	0	865,049.73	0.00	865,049.73
Total		4,570,379.10	0.00	4,570,379.10

$TC_{kj} = DC_{kj} + IC_{kj}$ = Total Distribution Cost in Region j (1986 $)

$X_{ij} = \begin{cases} 0 & \text{if customers of type i in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$

DIRECT - FACTORY-CUSTOMER SHIPMENTS COST CALCULATIONS

Factory Region k = II Rocky Mountain
Market Region j = I West Coast

Customer Type i	Annual Demand In Region j (MW/YR) d_{ij}	Average Delivery Quantity (MW/Ship) q_i	Number Shipments Per Year d_{ij}/q_i	Shipment Weight (kg) $Z_i = q_i * w$	Shipping Distance (km) s_{kj}	Shipment Cost ($) $C(Z_i, s_{kj})$	Annual Cost (1986 $/YR) DC_{kj}
1 Residential Household	50.0	.01	5000	1559.25	640	$356.03 (Truck)	3,272,805.70
2 Intermediate Commercial	25.0	.50	50	77,962.50	640	$4,705.19 (Rail)	432,523.67
3 Central Station Utility	50.0	5.00	10	779,625.00	640	$47,051.93 (Rail)	865,049.73

w = Solar Array Unit Weight (kg/MW)
= 155,925 kg/MW

DC_{kj} = Annual distribution cost in Region j for customers supplied directly from the factory in Region k (in manufacturing year dollars)

$$= \sum_{i=1}^{3} \frac{d_{ij}}{q_i} * (1-X_{ij}) * C(Z_i, s_{kj}) (1+g_T)^{1986-1977}$$

where

$$X_{ij} = \begin{cases} 0 & \text{if customers of type in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$$

Transportation Inflation Rate
g_T = 7%/year

WAREHOUSING COST CALCULATION FOR REGION j = I WEST COAST

Shipment QTY Q_j (MW)	.25	.50		1.00	1.50	2.00	2.50
Warehouse size $F = 353.95\ Q_j\ m^2$	88.4875	176.975		353.95	530.925	707.90	884.875
Equipment Cost $E = (1.07)^9 * Ke\ (F_j) * ej$	4,492	8,984		17,968	26,952	35,936	47,919
Facilities Cost $B = (1.09)^9 * K_b\ (F_j) * bj$	50,201	100,401		196,845	290,508	384,171	477,835
Warehouse Lease Cost (1986 $/YR) $LC_j\ (Q_j) = .25E + .126B$	7,448	14,897		29,294	43,342	57,389	71,437
Personnel Cost $(1.08)^9 * P(F_j) * lj$	60,445	60,445		60,445	60,445	60,445	60,445
Utilities Cost $(1.12)^9 * 1.20 * uj * Fj$	389	777		1,555	2,332	1,310	3,887
Property Tax, Maintenance and Insurance $.06*(E + B)$	3,282	6,563		12,889	19,048	25,206	31,365
Warehouse Operating Cost (1986 $/YR) $OC\ (Q\ )$	64,116	67,785		74,889	81,825	86,961	95,697
Inventory Carrying Cost (1986 $/YR) $CC(Q_j) = 94375 * Q_j$	23,594	47,188		94,375	141,562	188,750	235,938
Warehousing Cost (1986 $/YR) $W_j(Q_j) = CC(Q_j) + OC_j(Q_j) + LC_j(Q_j)$	95,158	129,870		198,558	266,729	333,100	403,072

Regional Cost Indices

e_j = Equipment = 1.062

b_j = Facilities = 1.062

l_j = Labor = 1.103

u_j = Utilities = 1.320

Inflation Rates

g_J = Equipment = 7%

g_H = Facilities = 9%

g_B = Labor = 8%

g_E = Utilities = 12%

g_T = Transportation = 7%

ANNUAL DISTRIBUTION COST FOR WAREHOUSE TRANSSHIPMENTS
IN REGION j = I WEST COAST
FACTORY LOCATION REGION k = II ROCKY MOUNTAIN

Customer Type i	x_{ij}	d_{ij}	$x_{ij} * d_{ij}$	q_i	$(d_{ij} * x_{ij}/q) * 1 + \frac{q_i * w}{WC} * Y_{ij}$	Y_{ij}
1 Household	1	50.0	50.0	.01	298,726.56	50.0
2 Intermediate	0	25.0	0.0	.50	0.00	50.0
3 Central Station	0	50.0	0.0	5.00	0.00	50.0
Σ		125.0	50.0		KM = 298,726.56	

Warehouse - customer distance = y_{ij}

Factory-warehouse distance = s_{kj} = 640 km

Solar Array Unit Weight = w = 155,925 kg/MW

FC = $24,039/year

VC = $.095/km

MC = 75,000 km/vehicle

WC = 8,000 kg/delivery

Warehouse Order Quantity Q_j (MW)		.50	1.00	1.50		5.00
Weight = $q_j * w$		77,962.15	155,925	233,881.5		779,625
Deliveries/Year $\frac{d_{ij} \; x_{ij}}{Q_j}$		100	50	33.33		10
Order processing cost @$50/delivery		5,000	2,500	1,667		500
Cost/delivery $C(Q_j * W, S_{kj})$						
Inflation Factor = (1 + .07)		4,705	9,410	14,116		47,052
Annual Transportation Cost T_{kj} (Q_j) (1986 Dollars)		874,223	869,646	868,095		865,969
Inventory Carrying Cost $CC(Q_j)$		41,188	94,375	141,562		
Warehouse Operating Cost $OC_j(Q_j)$		67,785	74,889	81,825		
Warehouse Leasing Cost $LC_j(Q_j)$		14,897	29,294	43,342		
Annual Warehousing Cost W_j (Q_j) (1986 Dollars)		129,870	198,558	266,729		721,769
Fixed Delivery Cost $\frac{FC}{MC} * KM$		176,028	176,028	176,028		176,028
Variable Delivery Cost VC*KM		52,174	52,174	52,174		52,174
Annual Local Delivery Costs L_j (1986 Dollars)		228,202	228,202	228,202		228,202
Total Annual Distribution Cost for Region j Transshipments (1986 $) $IC_{kj}(Q_j)$		1,232,295	1,296,406	1,363,026		1,815,940

$IC_{kj}(Q_j) = T_{kj}(Q_j) + W_j(Q_j) + L_j$

DIRECT - FACTORY-CUSTOMER SHIPMENTS COST CALCULATIONS

Factory Region k = II Rocky Mountain
Market Region j = II Rocky Mountain

Customer Type i	Annual Demand In Region j (MW/YR) d_{ij}	Average Delivery Quantity (MW/Ship) q_i	Number Shipments Per Year d_j / q_i	Shipment Weight (kg) $Z_i = q_i * w$	Average Shipping Distance (km) Y_{ij}	Average Shipment Cost (1986 $)	Total Annual Cost (1986 $/YR) DC_{kj}
1 Residential Household	60.0	.01	600	1559.25	50.0	213.245	127,947
2 Intermediate Commercial	30.0	.50	60	77,962.50	50.0	1,066.233	63,974
3 Central Station Utility	50.0	5.00	10	779,625.00	50.0	10,662.330	106,623
Totals	140.0	.21	670	32,581.34	50.0	445.588	298,544

DC_{kk} = Annual distribution cost in Region k for customers supplied directly from the factory in Region k (in Manufacturing Year Dollars)

$$= \sum_{i=1}^{3} \frac{d_{ij}}{q_i} * 1 + \frac{q_i * w}{WC} * Y_{ij} * \frac{FC}{MC} + VC * (1 + g_T)^n$$

w = 155,925 kg/MW

FC = $24,039/year

VC = $.095/km

MC = 75,000 km/vehicle

WC = 8,000 kg/delivery

g_T = Transportation inflation rate = 7%

n = 1986-1977 = 9

Fleet size = 6 Trucks

Distance = 390,806,266 km/yr

Fixed Cost = $230,288

Variable cost = $68,256

Total cost = $298,544

TOTAL ANNUAL DISTRIBUTION COST CALCULATIONS
FROM THE FACTORY IN REGION k = II ROCKY MOUNTAIN
TO CUSTOMERS IN REGION j = III NORTH CENTRAL

Customer Type i	Shipping Indicator X_{ij}	Annual Direct Shipping Cost (1986 $) DC_{kj}	Annual Distribution Costs For Transshipments (1986 $) IC_{kj}	Total Annual Distribution Cost Region j (1986 $) TC_{kj}
1	1	0.00		
2	1	0.00		
3	0	0.00	0.00	0.00
Total		0.00	955,283.00	955,283.00
1	0	1,397,039.30	0.00	1,397,039.30
2	1	0.00	376,536.00	376,536.00
3	0	0.00	0.00	0.00
Total		1,397,039.30	376,536.00	1,773,575.30
1	1	0.00	665,811.00	665,811.00
2	0	283,216.62	0.00	283,216.62
3	0	0.00	0.00	0.00
Total		283,216.62	665,811.00	949,027.62
1	0	1,397,039.30	0.00	1,397,039.30
2	0	283,216.62	0.00	283,216.62
3	0	0.00	0.00	0.00
Total		1,680,225.90	0.00	1,680,225.90

$TC_{kj} = DC_{kj} + IC_{kj}$ = Total Distribution Cost in Region j (1986 $)

$X_{ij} = \begin{cases} 0 & \text{if customers of type i in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$

DIRECT - FACTORY-CUSTOMER SHIPMENTS COST CALCULATIONS

Factory Region k = II Rocky Mountain
Market Region j = III North Central

Customer Type i	Annual Demand In Region j (MW/YR) d_{ij}	Average Delivery Quantity (MW/Ship) q_i	Number Shipments Per Year d_{ij}/q_i	Shipment Weight (kg) $Z_i = q_i * w$	Average Shipping Distance (km) S_{kj}	Average Shipment Cost ($) $C(Z_i, S_{kj})$	Total Annual Cost (1986 $/YR) DC_{kj}
1 Residential Household	10	.01	1000	1,559.25	2100	759.88 (Truck)	1,397,039.30
2 Intermediate Commercial	5	.50	10	77,962.50	2100	15,404.76 (Rail)	283,216.62
3 Central Station Utility	0.0	.00	0	0.00	2100	0.00	0.00

w = Solar Array Unit Weight (kg/MW)
= 155,925 kg/MW

DC_{kj} = Annual distribution cost in Region j for customers supplied directly from the factory in Region k (in manufacturing year dollars)

$$= \sum_{i=1}^{3} \frac{d_{ij}}{q_i} * (1-X_{ij}) * C(Z_i, S_{kj}) (1+g_T)^{1986-1977}$$

where

$$X_{ij} = \begin{cases} 0 & \text{if customers of type in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$$

Transportation Inflation Rate
g_T = 7%/year

WAREHOUSING COST CALCULATION FOR REGION j = III NORTH CENTRAL

Shipment QTY Q_j (MW)		.10		.20*		.30	
Warehouse size $F = 353.95\ Q_j$ (m^2)		35,395		70,790		106,185	
Equipment Cost $E = (1.07)^9 * Ke\ (Fj) * ej$		1,780		3,560		5,340	
Facilities Cost $B = (1.09)^9 * K_b\ (F_j) * bj$		19,891		39,782		59,674	
Warehouse Lease Cost (1986 $/YR) $LC_j(Q_j) = .25E + .126B$		2,951		5,902		8,854	
Personnel Cost $(1.08)^9 * P(F_j) * lj$		55,568		55,568		55,568	
Utilities Cost $(1.12)^9 * 1.20 * uj * Fj$		106		212		318	
Property Tax, Maintenance and Insurance $.06*(E + B)$		1,300		2,600		3,900	
Warehouse Operating Cost (1986 $/YR) $OC_j(Q_j)$		56,974		58,380		59,786	
Inventory Carrying Cost (1986 $/YR) $CC(Q_j) = 94375 * Q_j$		9,438		18,875		28,312	
Warehousing Cost (1986 $/YR) $W_j(Q_j) = CC(Q_j) + OC_j(Q_j) + LC_j(Q_j)$		69,363		83,157		96,952	

Regional Cost Indices

e_j = Equipment = 1.052

b_j = Facilities = 1.052

l_j = Labor = 1.014

u_j = Utilities = .900

Inflation Rates

g_J = Equipment = 7%

g_H = Facilities = 9%

g_B = Labor = 8%

g_E = Utilities = 12%

g_T = Transportation = 7%

ANNUAL DISTRIBUTION COST FOR WAREHOUSE TRANSSHIPMENTS
IN REGION j = III NORTH CENTRAL
FACTORY LOCATION REGION k = II ROCKY MOUNTAIN

Customer Type i	x_{ij}	d_{ij}	$x_{ij} * d_{ij}$	q_i	$(d_{ij} * x_{ij} / q_i) * 1 + \frac{q_i * w}{WC} * Y_{ij}$	Y_{ij}
1 Household	1	50.0	10.0	.01	59,745.31	50.0
2 Intermediate	0	25.0	0.0	.50	0.00	50.0
3 Central Station	0	50.0	0.0	5.00	0.00	50.0
Σ		125.0	10.0		KM = 59,745.31	

Warehouse - customer distance = Y_{ij}

Factory-warehouse distance = s_{kj} = 2,100km

Solar Array Unit Weight = w = 155,925 kg/mw

FC = $24,039/year

VC = $.095/km

MC = 75,000 km/vehicle

WC = 8,000 kg/delivery

Warehouse Order Quantity Q (MW)		.10	.20	.30		
Weight = $q_i * w$		15,592.5	31,185.0	46,777.5		
Deliveries/Year = $\Sigma d_{ij} \; x_{ij} \; / Q_j$		100	50	33.33		
Order processing cost @$50/delivery		5,000	2,500	1,667		
Cost/delivery $C(Q_j * W, S_{kj})$ Inflation Factor = (1 + .07)		4,563	6,244	9,243		
Annual Transportation Cost $T_{kj} \; (Q_j)$ (1986 Dollars)		848,165	578,550	569,485		
Inventory Carrying Cost $CC(Q_j)$		9,438	18,875	28,312		
Warehouse Operating Cost $OC \; (Q_j)$		56,974	58,380	59,786		
Warehouse Leasing Cost $LC \; (Q_j)$		2,951	5,902	8,854		
Annual Warehousing Cost $W_j \; (Q_j)$ (1986 Dollars)		69,363	83,157	96,952		
Fixed Delivery Cost $\frac{FC}{MC} * KM$		35,206	35,206	35,206		
Variable Delivery Cost VC*KM Inflation Factor = $(1+q_T)^n$ = 1.83846		10,435	10,435	10,435		
Annual Local Delivery Costs L_j (1986 Dollars)		45,641	45,641	45,641		
Total Annual Distribution Cost for Region j Transshipments (1986 $) $ICK_j(Q_j)$		921,632	665,811	670,541		
$IC_{kj}(Q_j) = T_{kj} \; (Q_j) + W_j \; (Q_j) + L_j$						

TOTAL ANNUAL DISTRIBUTION COST CALCULATIONS
FROM THE FACTORY IN REGION k = II ROCKY MOUNTAIN
TO CUSTOMERS IN REGION j = IV GREAT LAKES

Customer Type i	Shipping Indicator X_{ij}	Annual Direct Shipping Cost (1986 $) DC_{kj}	Annual Distribution Costs For Transshipments (1986 $) IC_{kj}	Total Annual Distribution Cost Region j (1986 $) TC_{kj}
1	1	0.00		
2	1	0.00		
3	0	0.00	0.00	0.00
Total		0.00	1,238,369.00	1,238,369.00
1	0	1,743,872.40	0.00	1,743,872.40
2	1	0.00	473,909.00	473,909.00
3	0	0.00	0.00	0.00
Total		1,743,872.40	473,909.00	2,217,781.40
1	1	0.00	852,920.00	852,920.00
2	0	375,103.63	0.00	375,103.63
3	0	0.00	0.00	0.00
Total		375,103.63	852,920.00	1,228,023.63
1	0	1,743,872.40	0.00	1,743,872.40
2	0	375,103.63	0.00	375,103.63
3	0	0.00	0.00	0.00
Total		2,118,976.00	0.00	2,118,976.00

$TC_{kj} = DC_{kj} + IC_{kj}$ = Total Distribution Cost in Region j (1986 $)

$$X_{ij} = \begin{cases} 0 & \text{if customers of type i in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$$

DIRECT – FACTORY-CUSTOMER SHIPMENTS COST CALCULATIONS

Factory Region k = II Rocky Mountain
Market Region j = IV Great Lakes

Customer Type i	Annual Demand In Region j (MW/YR) d_{ij}	Average Delivery Quantity (MW/Ship) q_i	Number Shipments Per Year d_{ij}/q_i	Shipment Weight (kg) $Z_i = q_i * w$	Average Shipping Distance (km) S_{kj}	Average Shipment Cost ($) $C(Z_i, S_{kj})$	Total Annual Cost (1986 $/YR) DC_{kj}
1 Residential Household	10.0	.01	1000	1,559.25	2782	948.53 (Truck)	1,743,872.40
2 Intermediate Commercial	5.0	.50	10	77,962.50	2782	20,402.79 (Rail)	375,103.63
3 Central Station Utility	0.0	.00	0	0.00	2782	0.00	0.00

w = Solar Array Unit Weight (kg/MW)
= 155,925 kg/MW

DC_{kj} = Annual distribution cost in Region j for customers supplied directly from the factory in Region k (in manufacturing year dollars)

$$= \sum_{i=1}^{3} \frac{d_{ij}}{q_i} * (1-X_{ij}) * C(Z_i, S_{kj}) (1+g_T)$$

where

X_{ij} = 0 if customers of type i in Region j are supplied directly from the factory

1 if customers of type i in Region j are supplied from a warehouse in Region j

Transportation Inflation Rate
g_T = 7%/year

WAREHOUSING COST CALCULATION FOR REGION j = IV GREAT LAKES

Shipment QTY Q_j (MW)		.10		.20*		.30	
Warehouse size F_j = 353.95 Q_j m^2		35,395		70,790		106,185	
Equipment Cost $E = (1.07)^t * K_e(F_j) * e_j$		21,692		3,384		5,076	
Facilities Cost $B = (1.09)^t * K_b(F_j) * b_j$		18,908		37,816		56,724	
Warehouse Lease Cost (1986 $/YR) $LC(Q_j) = .25E + .126B$		2,805		5,611		8,416	
Personnel Cost $(1.08)^t * P(F_j) * l_j$		63,624		63,624		63,624	
Utilities Cost $(1.12)^t * 1.20 * u_j * F_j$		106		212		318	
Property Tax, Maintenance and Insurance $.06*(E + B)$		1,236		2,472		3,708	
Warehouse Operating Cost (1986 $/YR) $OC_j(Q_j)$		64,966		66,308		67,650	
Inventory Carrying Cost (1986 $/YR) $CC(Q_j) = 94375 * Q_j$		9,438		18,875		28,312	
Warehousing Cost (1986 $/YR) $W(Q_j) = CC(Q_j) + OC_j(Q_j) + LC_j(Q_j)$		77,209		90,794		104,378	

Regional Cost Indices

e_j = Equipment = 1.000

b_j = Facilities = 1.000

l_j = Labor = 1.161

u_j = Utilities = .900

Inflation Rates

g_E = Equipment = 7%

g_H = Facilities = 9%

g_B = Labor = 8%

g_E = Utilities = 12%

g_T = Transportation = 7%

ANNUAL DISTRIBUTION COST FOR WAREHOUSE TRANSSHIPMENTS
IN REGION j = IV GREAT LAKES
FACTORY LOCATION REGION k = II ROCKY MOUNTAIN

Customer Type i	x_{ij}	d_{ij}	$x_{ij} * d_{ij}$	q_i	$(d_{ij} * x_{ij} / Q)^* 1 + \frac{q_i * w}{WC} * y_{ij}$	Y_{ij}
1 Household	1	10.0	10.0	.01	59,745.31	50.0
2 Intermediate	0	5.0	0.0	.50	0.00	50.0
3 Central Station	0	0.0	0.0	0.00	0.00	50.0
Σ		15.0	10.0	.51	KM = 59,745.31	

Warehouse - customer distance = y_{ij}

Factory-warehouse distance = s_{kj} = 2,782km

Solar Array Unit Weight = w = 155,925 kg/MW

FC = $24,039/year

VC = $.095/km

MC = 75,000 km/vehicle

WC = 8,000 kg/delivery

Warehouse Order Quantity Q_j (MW)			.10	.20	.30	
Weight = $q_i * w$			15,592.5	31,185.0	46,777.5	
Deliveries/Year = $\Sigma d_{ij} x_{ij} / Q$			100	50	33.33	
Order processing cost @$50/delivery			5,000	2,500	1,667	
Cost/delivery $C(Q_j * W, S_{kj})$ Inflation Factor = $(1 + .07)^9$			5,770	8,196	12,242	
Annual Transportation Cost T_{kj} (Q_j) (1986 Dollars)			1,070,062	758,022	753,258	
Inventory Carrying Cost $CC(Q_j)$			9,438	18,875	28,312	
Warehouse Operating Cost $OC_j(Q_j)$			64,966	66,308	67,650	
Warehouse Leasing Cost $LC_j(Q_j)$			2,805	5,611	8,416	
Annual Warehousing Cost W_j (Q_j) (1986 Dollars)			77,209	90,794	104,378	
Fixed Delivery Cost $\frac{FC}{MC} * KM$			35,206	35,206	35,206	
Variable Delivery Cost VC*KM Inflation Factor = $(1+q_T)^4$ = 1.83846			10,435	10,435	10,435	
Annual Local Delivery Costs L_j (1986 Dollars)			45,641	45,641	45,641	
Total Annual Distribution Cost for Region j Transshipments (1986 $) $IC_{kj}(Q_j)$			1,151,375	852,920	861,740	
$IC_{kj}(Q_j) = T_{kj}(Q_j) + W_j(Q_j) + L_j$						

TOTAL ANNUAL DISTRIBUTION COST CALCULATIONS
FROM THE FACTORY IN REGION k = II ROCKY MOUNTAIN
TO CUSTOMERS IN REGION j = V NORTH EASTERN

Customer Type i	Shipping Indicator X_{ij}	Annual Direct Shipping Cost (1986 $) DC_{kj}	Annual Distribution Costs For Transshipments (1986 $) IC_{kj}	Total Annual Distribution Cost Region j (1986 $) TC_{kj}
1	1	0.00		
2	1	0.00		
3	0	0.00		
Total		0.00	8,173,641.00	8,173,641.00
1	0	4,314,665.30	0.00	4,314,665.30
2	1	0.00		
3	0	0.00		
Total		4,314,665.30	6,088,514.00	10,403,179.30
1	1	0.00		
2	0	974,241.37	0.00	974,241.37
3	0	0.00		
Total		974,241.37	7,168,512.00	8,142.753.37
1	0	0.00		
2	0	0.00		
3	0	4,871,207.70	0.00	4,871,207.70
Total		4,871,207.70	3,151,074.00	8,022,281.70
1	0	4,314,665.30	0.00	4,314,665.30
2	0	974,241.37	0.00	974,241.37
3	1	0.00	5,083,379.00	5,083,379.00
Total		5,288,906.67		10,372,285.67
1	0	4,314,665.30	0.00	4,314,665.30
2	1	0.00	1,063,053.00	1,063,053.00
3	0	4,871,207.70	0.00	4,871,207.70
Total		9,185,873.00	1,063,053.00	10,248,926.00
1	1	0.00	2,145,472.00	2,145,472.00
2	0	974,241.37	0.00	974,241.37
3	0	4,871,207.70	0.00	4,871,207.70
Total		5,045,449.07	2,145,472.00	7,990,921.07*
1	0	4,314,665.30	0.00	4,314,665.30
2	0	974,241.37	0.00	974,241.37
3	0	4,871,207.70	0.00	4,871,207.70
Total		10,160,114.37	0.00	10,160,114.37

$TC_{kj} = DC_{kj} + IC_{kj}$ = Total Distribution Cost in Region j (1986 $/Year)

$$X_{ij} = \begin{cases} 0 & \text{if customers of type i in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$$

DIRECT - FACTORY-CUSTOMER SHIPMENTS COST CALCULATIONS

Factory Region k = II Rocky Mountain
Market Region k = V North Eastern

Customer Type i	Annual Demand In Region j (MW/YR) d_{ij}	Average Delivery Quantity (MW/Ship) q_i	Number Shipments Per Year d_{ij}/q	Shipment Weight (kg) $z_i = q_i * w$	Average Shipping Distance (km) S_{kj}	Average Shipment Cost ($) $C(Z_i, S_{kj})$	Total Annual Cost (1986 $/YR) DC_{kj}
1 Residential Household	20.0	.01	2000	1,559.25	3595	1,173.42 (Truck)	4,314,665.30
2 Intermediate Commercial	10.0	.50	20	77,962.50	3595	26,495.55 (Rail)	974,241.37
3 Central Station Utility	50.0	5.00	10	779,625.00	3595	264,955.55	4,871,207.70

w = Solar Array Unit Weight (kg/MW)
= 155,925 kg/MW

DC_{kj} = Annual distribution cost in Region j for customers supplied directly from the factory in Region k (in manufacturing year dollars)

$$= \sum_{i=1}^{3} \frac{d_{ij}}{q_i} * (1-X_{ij}) * C(z_i, S_{KJ})(1+g_T)$$

where

$$x_{ij} = \begin{cases} 0 & \text{if customers of type in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$$

Transportation Inflation Rate
g_T = 7%/year

WAREHOUSING COST CALCULATION FOR REGION j = V NORTH EASTERN

Shipment QTY Q (MW)	.20	.40*	.60	1.00	1.20	1.40	1.60
Warehouse size F_j = 353.95 Q_j m^2	70,790	141.58	212.37	353.95	424.74	495.53	566.32
Equipment Cost $E = (1.07)^9 * K (F_j) * e_j$	3,770	7,539	11,309	18,848	22,617	26,387	30,156
Facilities Cost $B = (1.09)^9 * K_b (F_j) * b_j$	42,127	84,254	126,381	206,483	245,783	285,083	324,383
Warehouse Lease Cost (1986 $/YR) $LC_j(Q_j) = .25E + .126B$	6,250	12,501	18,751	30,729	36,623	42,517	48,411
Personnel Cost $(1.08)^9 * P(F_j) * l_j$	54,691	54,691	54,691	54,691	54,691	54,691	54,691
Utilities Cost $(1.12)^9 * 1.20 * u_j * F_j$	306	612	861	1,531	1,837	2,144	2,445
Property Tax, Maintenance and Insurance .06*(E + B)	2,754	5,508	8,261	13,520	16,104	18,688	21,272
Warehouse Operating Cost (1986 $/YR) $OC_j(Q_j)$	57,751	60,811	63,813	69,742	72,632	75,523	78,408
Inventory Carrying Cost (1986 $/YR) $CC(Q_j) = 94375 * Q_j$	18,875	37,750	56,625	94,375	113,250	132,125	151,000
Warehousing Cost (1986 $/YR) $W_j(Q_j) = CC(Q_j) + OC_j(Q_j) + LC_j(Q_j)$	82,876	111,062	139,189	194,846	222,505	250,165	277,819

Regional Cost Indices

e_j = Equipment = 1.114

b_j = Facilities = 1.114

l_j = Labor = .998

u_j = Utilities = 1.300

Inflation Rates

g_J = Equipment = 7%

g_H = Facilities = 9%

g_B = Labor = 8%

g_E = Utilities = 12%

g_T = Transportation = 7%

ANNUAL DISTRIBUTION COST FOR WAREHOUSE TRANSSHIPMENTS
IN REGION j = V NORTH EASTERN
FACTORY LOCATION REGION k = II ROCKY MOUNTAIN

Customer Type i	x_{ij}	d_{ij}	$x_{ij} * d_{ij}$	q_i	$(d_{ij} * x_{ij}/q_i) * 1+\frac{q_i * w}{WC} * Y_{ij}$	Y_{ij}
1 Household	1	20.0	20.0	.01	119,490.63	50.0
2 Intermediate	0	10.0	0.0	.50	0.00	50.0
3 Central Station	0	50.0	0.0	0.00	0.00	50.0
		80.0	20.0	.51	KM = 59,745.31	

Warehouse - customer distance = y_{ij}

Factory-warehouse distance = s_{kj} = 3,595 km

Solar Array Unit Weight = w = 155,925 kg/MW

FC = $24,039/year

VC = $.095/km

MC = 75,000 km/vehicle

WC = 8,000 kg/delivery

Warehouse Order Quantity Q_j (MW)	.10	.15	.20	.25	.40	1.00
Weight = $q_j * w$	15,592.5	23,388.75	31,185	38,981	62,370	155,925
Deliveries/Year = $\sum d_{ij} x_{ij} / Q_j$	200	133.33	100	80	50	20
Order processing cost @$50/delivery	10,000	6,667	5,000	4,000	2,500	1,000
Cost/delivery $C(Q_j * W, S_{kj})$ Inflation Factor = $(1 + .07)^9$	7,209	7,893	10,544	13,180	21,089	52,722
Annual Transportation Cost $T_{kj}(Q_j)$ (1986 Dollars)	2,669,160	1,947,000	1,947,725	1,945,887	1,943,129	1,940,371
Inventory Carrying Cost $CC(Q_j)$	9,438	14,156	18,875	23,594	37,750	94,375
Warehouse Operating Cost $OC_j(Q_j)$	56,221	56,986	57,751	58,516	60,811	69,742
Warehouse Leasing Cost $LC_j(Q_j)$	3,125	4,688	6,250	7,813	12,501	30,729
Annual Warehousing Cost $W_j(Q_j)$ (1986 Dollars)	68,784	75,830	82,876	89,923	111,062	194,846
Fixed Delivery Cost $\frac{FC}{MC} * KM$	70,411	70,411	70,411	70,411	70,411	70,411
Variable Delivery Cost VC*KM Inflation Factor = $(1+g_T)^n$ = 1.83846	20,870	20,870	20,870	20,870	20,870	20,870
Annual Local Delivery Costs L_j (1986 Dollars)	91,281	91,281	91,281	91,281	91,281	91,281
Total Annual Distribution Cost for Region j Transshipments (1986 $) $IC_{kj}(Q_j)$	2,829,225	2,114,111	2,121,882	2,127,091	2,145,472	2,226,498
$IC_{kj}(Q_j) = T_{kj}(Q_j) + W_j(Q_j) + L_j$						

TOTAL ANNUAL DISTRIBUTION COST CALCULATIONS
FROM THE FACTORY IN REGION k = II ROCKY MOUNTAIN
TO CUSTOMERS IN REGION j = VI SOUTH EASTERN

Customer Type i	Shipping Indicator X_{ij}	Annual Direct Shipping Cost (1986 $) DC_{kj}	Annual Distribution Costs For Transshipments (1986 $) IC_{kj}	Total Annual Distribution Cost Region j (1986 $) TC_{kj}
1	1	0.00		
2	1	0.00		
3	0	0.00	0.00	0.00
Total		0.00	1,369,336.00	1,369,336.00
1	0	1,873,050.30	0.00	1,873,050.30
2	1	0.00	490,236.00	490,236.00
3	0	0.00	0.00	0.00
Total		1,873,050.30	490,236.00	2,363,286.30
1	1	0.00	944,205.00	944,205.00
2	0	409,327.64	0.00	409,327.64
3	0	0.00	0.00	0.00
Total		409,327.64	944,205.00	1,353,532.64*
1	0	1,873,050.30	0.00	1,873,050.30
2	0	409,327.64	0.00	409,327.64
3	0	0.00	0.00	0.00
Total		2,282,377.94	0.00	2,282,377.94

$TC_{kj} = DC_{kj} + IC_{kj}$ = Total Distribution Cost in Region j (1986 $)

$$X_{ij} = \begin{cases} 0 & \text{if customers of type i in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$$

DIRECT - FACTORY-CUSTOMER SHIPMENTS COST CALCULATIONS

Factory Region k = II Rocky Mountain
Market Region j = VI South Eastern

Customer Type i	Annual Demand In Region j (MW/YR) d_{ij}	Average Delivery Quantity (MW/Ship) q_i	Number Shipments Per Year d_{ij}/q_i	Shipment Weight (kg) $z_i = q_i * w$	Average Shipping Distance (km) S_{kj}	Average Shipment Cost ($) $C(Z_i, S_{kj})$	Total Annual Cost (1986 $/YR) DC_{kj}
1 Residential Household	10.0	.01	1000	1,559.25	3036	1,173.42 (Truck)	1,873,050.30
2 Intermediate Commercial	5.0	.50	10	77,962.50	3036	22,264.22 (Rail)	409,327.64
3 Central Station Utility	0.0	.00	0	0.00	3036	0.00	0.00

w = Solar Array Unit Weight (kg/MW)
= 155,925 kg/MW

DC_{kj} = Annual distribution cost in Region j for customers supplied directly from the factory in Region k (in manufacturing year dollars)

$$= \sum_{i=1}^{3} \frac{d_{ij}}{q_i} * (1-X_{ij}) * C(z_i, S_{kj}) (1+g_T)$$

where

$$X_{ij} = \begin{cases} 0 & \text{if customers of type in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$$

Transportation Inflation Rate
g_T = 7%/year

WAREHOUSING COST CALCULATION FOR REGION j = VI SOUTH EASTERN

Shipment QTY Q_j (MW)		.10		.20*		.30	.40
Warehouse size $F_j = 353.95\ Q_j\ m^2$		35,395		70,790		106,185	141,358
Equipment Cost $E = (1.07)^9 * K_E(F_j) * e_j$		1,587		3,174		4,761	6,338
Facilities Cost $B = (1.09)^9 * K_L(F_j) * b_j$		17,736		35,471		53,207	70,831
Warehouse Lease Cost (1986 $/YR) $LC_j(Q_j) = .25E + .126B$		2,631		5,263		7,894	10,509
Personnel Cost $(1.08)^9 * P(F_j) * l_j$		47,019		47,019		47,019	47,019
Utilities Cost $(1.12)^9 * 1.20 * u_j * F_j$		112		224		336	447
Property Tax, Maintenance and Insurance $.06*(E + B)$		1,159		2,319		3,478	4,630
Warehouse Operating Cost (1986 $/YR) $OC_j(Q_j)$		48,290		49,562		50,833	52,096
Inventory Carrying Cost (1986 $/YR) $CC(Q_j) = 94375 * Q_j$		9,438		18,875		28,312	37,750
Warehousing Cost (1986 $/YR) $W_j(Q_j) = CC(Q_j) + OC_j(Q_j) + LC_j(Q_j)$		60,359		73,700		87,039	100,355

*Optimal Level

Regional Cost Indices

e_j = Equipment = .938

b_j = Facilities = .938

l_j = Labor = .858

u_j = Utilities = .950

Inflation Rates

g_J = Equipment = 7%

g_H = Facilities = 9%

g_B = Labor = 8%

g_E = Utilities = 12%

g_T = Transportation = 7%

ANNUAL DISTRIBUTION COST FOR WAREHOUSE TRANSSHIPMENTS
IN REGION j = VI South Eastern
FACTORY LOCATION REGION k = II Rocky Mountain

Customer Type i	x_{ij}	d_{ij}	$x_{ij} * d_{ij}$	q_i	$(d_{ij} * x_{ij}/q_i) * 1+\frac{q_i * w}{WC} * y_{ij}$	y_{ij}
1 Household	1	10.0	10.0	.01	59,745.31	50.0
2 Intermediate	0	5.0	0.0	.50	0.00	50.0
3 Central Station	0	0.0	0.0	0.00	0.00	50.0
		15.0	10.0	5.51	KM = 59,745.31	

Warehouse - customer distance = y_{ij}

Factory-warehouse distance = s_{kj} = 3,036 km

Solar Array Unit Weight = w = 155,925 kg/MW

FC = $24,039/year

VC = $.095/km

MC = 75,000 km/vehicle

WC = 8,000 kg/delivery

Warehouse Order Quantity Q_j (MW)				.10	.20	.30
Weight = $q_j * w$				15,592.5	31,185.0	46,777.5
Deliveries/Year = $\sum d_{ij}\ x_{ij}\ /Q_j$				100	50	33.33
Order processing cost @$50/delivery				5,000	2,500	1,667
Cost/delivery $C(Q_j * W, S_{kj})$ Inflation Factor = (1 + .07)				6,220	8,923	13,359
Annual Transportation Cost T_{kj} (Q_j) (1986 Dollars)				1,152,703	824,864	821,619
Inventory Carrying Cost $CC(Q_j)$				9,438	18,875	28,312
Warehouse Operating Cost $OC_j(Q_j)$				48,290	49,562	50,833
Warehouse Leasing Cost $LC_j(Q_j)$				2,631	5,263	7,894
Annual Warehousing Cost W_j (Q_j) (1986 Dollars)				60,359	73,700	87,039
Fixed Delivery Cost $\frac{FC}{MC} * KM$				35,206	35,206	35,206
Variable Delivery Cost VC*KM Inflation Factor = $(1+q_T)^n$ = 1.83846				10,435	10,435	10,435
Annual Local Delivery Costs L_j (1986 Dollars)				45,641	45,641	45,641
Total Annual Distribution Cost for Region j Transshipments (1986 $) $IC_{kj}(Q_j)$				1,258,703	944,205	954,299
$IC_{kj}(Q_j) = T_{kj}(Q_j) + W_j(Q_j) + L_j$						

TOTAL ANNUAL DISTRIBUTION COST CALCULATIONS
FROM THE FACTORY IN REGION k = II ROCKY MOUNTAIN
TO CUSTOMERS IN REGION j = VII SOUTH CENTRAL

Customer Type i	Shipping Indicator X_{ij}	Annual Direct Shipping Cost (1986 $) DC_{kj}	Annual Distribution Costs For Transshipments (1986 $) IC_{kj}	Total Annual Distribution Cost Region j (1986 $) TC_{kj}
1	1	0.00		
2	1	0.00		
3	0	0.00		
Total		0.00	5,448,280.00	5,448,280.00
1	0	4,676,873.10	0.00	4,676,873.10
2	1	0.00		
3	0	0.00		
Total		4,676,873.10	3,378,060.00	8,054,933.10
1	1	0.00		
2	0	891,423.12	0.00	891,423.12
3	0	0.00		
Total		891,423.12	4,488,033.00	5,379,456.12
1	0	0.00		
2	0	0.00		
3	0	2,228,557.80	0.00	2,228,557.80
Total		2,228,557.80	3,087,954.00	5,316,511.80
1	0	4,676,873.10	0.00	4,676,873.10
2	0	891,423.12	0.00	891,423.12
3	1	0.00	2,417,814.00	2,417,814.00
Total		5,288,906.67		7,922,495.90
1	0	4,676,873.10	0.00	4,676,873.10
2	1	0.00	1,017,065.00	1,017,065.00
3	0	2,228,557.80	0.00	2,228,557.80
Total		9,185,873.00	1,063,053.00	10,248,926.00
1	1	0.00	2,127,709.00	2,127,709.00
2	0	891,423.12	0.00	891,423.12
3	0	2,228,557.80	0.00	2,228,557.80
Total		3,119,980.90	2,127,709.00	5,247,689.90*
1	0	4,676,873.10	0.00	4,676,873.10
2	0	891,423.12	0.00	891,423.12
3	0	2,228,557.80	0.00	2,228,557.80
Total		7,796,854.02	0.00	7,796,854.02

$TC_{kj} = DC_{kj} + IC_{kj}$ = Total Distribution Cost in Region j (1986 $)

$X_{ij} = \begin{cases} 0 & \text{if customers of type i in Region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in Region j are supplied from a warehouse in Region j} \end{cases}$

DIRECT - FACTORY - CUSTOMER SHIPMENTS COST CALCULATIONS

Factory Region k = II Rocky Mountain
Market Region j = VII South Central

	Customer Type	Annual Demand In Region J (MW/yr) d_{ij}	Average Delivery Quantity (MW/ship) q_i	Number Shipments Per Year d_{ij}/q_i	Shipment Weight $Z_i = q_i * w$	Shipping Distance S_{kj}	Shipping Cost $C(Z_i, S_{kj})$	Annual Cost DC_{kj}
1	Residential Household	40.0	.01	4000	1559.25	1652	635.96	4,676,873.10
11	Intermediate Commercial	20.0	.50	40	77,962.50	1652	12121.61	891,423.12
111	Central Station Utility	50.0	5.00	10	779.625.00	1652	121216.10	2,228,557.80

w = Solar Array Unit Weight (kg/MW)
= 155,925 kg/MW

DC_{kj} = Annual distribution cost in region j for customers supplied directly from the factory in Region k (in manufacturing year dollars)

$$= \sum_{i=1}^{3} \frac{d_{ij}}{q_i} * (1-X_{ij}) * C(Z_i, S_{kj})(1+g_T)^{1986-1977}$$

Where $X_{ij} = \begin{cases} 0 & \text{if customers of type i in region j are supplied directly from the factory} \\ 1 & \text{if customers of type i in region j are supplied from a warehouse in region j} \end{cases}$

TRANSPORTATION INFLATION RATE
g_T = 7%/year

WAREHOUSING COST CALCULATION FOR REGION j = VII SOUTH CENTRAL

Shipment QTY Q_j (MW)	.40	.80	1.00	1.20	1.40	1.80	2.20
Warehouse size $F_j = 353.95\ Q_j(m^2)$	141.58	283.16	353.95	424.74	495.53	637.11	778.69
Equipment Cost $E = (1.07)^9 * K_e(F_j) * e_j$	6,273	12,547	15,684	18,820	21,957	28,231	34,504
Facilities Cost $B = (1.09)^9 * K_b(F_j) * b_j$	70,111	139,120	171,822	204,525	237,228	302,633	368,039
Warehouse Lease Cost (1986 $/YR) $LC_j(Q_j) = .25E + .126B$	10,402	20,666	25,571	30,475	35,380	45,189	54,909
Personnel Cost $(1.08)^9 * P(F_j) * l_j$	51,348	51,348	51,348	51,348	51,348	51,348	51,348
Utilities Cost $(1.12)^9 * 1.20 * u_j * F_j$	565	1,131	1,413	1,696	1,979	2,544	3,109
Property Tax, Maintenance and Insurance $.06*(E + B)$	4,583	9,100	11,250	13,401	15,551	19,852	24,153
Warehouse Operating Cost (1986 $/YR) $OC_j(Q_j)$	56,496	61,579	64,011	66,445	68,878	73,744	78,610
Inventory Carrying Cost (1986 $/YR) $CC(Q_j) = 94375 * Q_j$	37,750	75,500	94,375	113,250	132,125	169,875	207,625
Warehousing Cost (1986 $/YR) $W_j(Q_j) = CC(Q_j) + OC_j(Q_j) + LC(Q_j)$	104,648	157,745	183,957	210,170	236,383	288,808	341,234

*Optimal Level

Regional Cost Indices

e_j = Equipment = .927

b_j = Facilities = .927

l_j = Labor = .937

u_j = Utilities = .200

Inflation Rates

g_J = Equipment = 7%

g_B = Facilities = 9%

g_B = Labor = 8%

g_E = Utilities = 12%

g_T = Transportation = 7%

ANNUAL DISTRIBUTION COST FOR WAREHOUSE TRANSSHIPMENTS
IN REGION j = II ROCKY MOUNTAIN
FACTORY LOCATION REGION k = VII SOUTH CENTRAL

Customer Type i	x_{ij}	d_{ij}	$x_{ij} * d_{ij}$	q_i	$(d_{ij} * x_{ij}) * \left(1+\frac{q_i * w}{WC}\right) * y_{ij}$	Y_{ij}
1 Household	1	40.0	40.0	.01	238,981.250	50.0
2 Intermediate	0	20.0	0.0	.50	0.000	50.0
3 Central Station	0	50.0	0.0	0.00	0.000	50.0
		110.0	40.0	5.51	KM = 238,981.250	

Warehouse - customer distance = y_{ij}

Factory-warehouse distance = s_{kj} = 1,652 km

Solar Array Unit Weight = w = 155,925 kg/MW

FC = $24,039/year

VC = $.095/km

MC = 75,000 km/vehicle

WC = 8,000 kg/delivery

Warehouse Order Quantity Q_j (MW)		.40	.80	1.00		
Weight = $q_j * w$		62,370	124,740	155,925		
Deliveries/Year = $d_{ij} x_{ij} / Q_j$		100	50	40		
Order processing cost @$50/delivery		5,000	2,500	2,000		
Cost/delivery $C(Q_j * W, S_{kj})$ Inflation Factor = $(1 + .07)^9$		9,697	19,395	24,243		
Annual Transportation Cost $T_{kj}(Q_j)$ (1986 Dollars)		1,791,999	1,787,402	1,786,484		
Inventory Carrying Cost $CC(Q_j)$		37,750	75,500	94,375		
Warehouse Operating Cost $OC_j(Q_j)$		56,496	61,579	64,011		
Warehouse Leasing Cost $LC_j(Q_j)$		10,402	20,666	25,571		
Annual Warehousing Cost $W_j(Q_j)$ (1986 Dollars)		104,648	157,745	183,957		
Fixed Delivery Cost $\frac{FC}{MC} * KM$		140,823	35,206	140,823		
Variable Delivery Cost VC*KM Inflation Factor = $(1+q_T)^h$ = 1.83846		41,739	41,739	41,739		
Annual Local Delivery Costs L_j (1986 Dollars)		182,562	182,562	182,562		
Total Annual Distribution Cost for Region j Transshipments (1986 $) $IC_{kj}(Q_j)$		2,079,209	2,127,709	2,153,003		

$IC_{kj}(Q_j) = T_{kj}(Q_j) + W_j(Q_j) + L_j$

FINANCIAL MODEL CALCULATIONS

INDEX

SALES REVENUES*
(By Product and Region)

Market Region j / Customer Type i	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Products
I West Coast	$82,417,748	$38,966,310	$70,161,132	$191,545,190
II Rocky Mountain	96,751,794	46,067,400	69,086,979	211,906,173
III North Central	16,952,037	8,032,317	0	24,984,354
IV Great Lakes	17,537,420	8,279,872	0	25,817,292
V North Eastern	34,660,244	16,492,347	75,458,516	126,611,107
VI South Eastern	16,987,530	8,078,540	0	25,066,070
VII South Central	65,945,158	31,378,876	71,786,047	169,110,081
All Regions	$331,251,931 (42.7%)	$157,295,662 (20.3%)	$286,492,674 (37.0%)	$775,040,267 (100.0%)

*Expressed in 1986 Manufacturing Year $/Year

COST OF GOODS SOLD*
(By Product and Region)

Market Region		Residential Household Products	Intermediate Commercial Products	Central Utility Stations	Total Cost of Good Sold
I	West Coast	$47,950,000	$23,975,000	$47,950,000	$119,875,000
II	Rocky Mountain	57,540,000	28,770,000	47,950,000	134,260,000
III	North Central	9,590,000	4,795,000	0	14,385,000
IV	Great Lakes	9,590,000	4,795,000	0	14,385,000
V	North Eastern	19,180,000	9,590,000	47,950,000	76,720,000
VI	South Eastern	9,590,000	4,795,000	0	14,385,000
VII	South Central	38,360,000	19,180,000	47,950,000	105,490,000
	All Regions	$191,800,000	$95,900,000	$191,800,000	$479,500,000

*Expressed in 1986 Manufacturing Year Dollars
Based on a Manufacturing Price of $.959/Peak Watt

MARKETING EXPENSES*
(By Product and Region)

Market Region j \ Customer Type	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Products
1 West Coast	$9,623,414	$3,425,556	$1,300,044	$14,349,014
11 Rocky Mountain	11,440,477	4,071,312	1,291,219	16,803,008
111 North Central	1,852,787	659,152	0	2,511,939
1V Great Lakes	2,083,809	744,090	0	2,827,899
V North Eastern	3,431,845	1,216,007	1,077,732	5,725,584
V1 South Eastern	1,599,745	566,058	0	2,165,803
V11 South Central	6,615,975	2,342,060	1,097,190	10,055,225
All Regions	$36,648,052	$13,024,235	$4,766,185	$54,438,472

*Expressed in 1986 Manufacturing Year Dollars/Year

DISTRIBUTION EXPENSES*
(By Product and Region)

Market Region j / Customer Type	Residential Household 1 From Warehouse	Commercial Intermediate 2 Direct	Public Utility Central Station 3 Direct	All Products
I West Coast	$1,296,406	$432,523	$856,050	$2,593,979
II Rocky Mountain	127,947	63,974	106,623	298,544
III North Central	665,811	283,217	0	949,028
IV Great Lakes	852,920	375,104	0	1,228,024
V North Eastern	2,145,472	974,241	4,871,208	7,990,921
VI South Eastern	944,205	409,328	0	1,353,533
VII South Central	2,127,709	891,423	2,228,558	5,247,690
All Regions	$8,160,470	$3,249,810	$8,071,439	$19,661,719

*Expressed in 1986 Manufacturing Year Dollars/Year.

INCOME TAXES*
(By Product and Region)

Market Region j \ Customer Type i	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Products
I West Coast	$12,009,443	$5,677,947	$10,223,480	$27,910,870
II Rocky Mountain	14,098,118	6,712,679	10,066,960	30,877,757
III North Central	2,470,154	1,170,423	0	3,640,577
IV Great Lakes	2,555,453	1,206,495	0	3,761,948
V North Eastern	5,050,493	2,403,171	10,995,383	18,449,047
VI South Eastern	2,475,325	1,177,159	0	3,652,484
VII South Central	9,609,152	4,572,351	10,460,252	24,641,755
All Regions	$48,268,138	$22,920,225	$41,746,075	$112,934,438

*Expressed in 1986 (manufacturing year) dollars.

NET PROFIT AFTER TAXES*
(By Product and Region)

Market Region j \ Customer Type i	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Products
I West Coast	$11,538,485	$5,455,283	$9,822,559	$26,816,327
II Rocky Mountain	13,545,251	6,449,436	9,672,177	29,666,864
III North Central	2,373,285	1,124,525	0	3,497,810
IV Great Lakes	2,455,239	1,159,182	0	3,614,421
V North Eastern	4,852,434	2,308,929	10,564,192	17,725,555
VI South Eastern	2,378,254	1,130,996	0	3,509,250
VII South Central	9,232,322	4,393,043	10,050,046	23,675,411
All Regions	$46,275,270	$22,021,394	$40,108,974	$108,505,638

*Expressed in 1986 (manufacturing year) dollars.

SOLAR ARRAY PRICE ESTIMATES*
(By Product and Region)
(1975 $/Watt)

Market Region j \ Customer Type i	Residential Household 1	Commercial Intermediate 2	Public Utility Central Station 3	All Products
I West Coast	$.860	$.813	$.732	$.799
II Rocky Mountain	.841	.801	.720	.789
III North Central	.884	.838	-	.868
IV Great Lakes	.914	.863	-	.897
V North Eastern	.904	.860	.787	.825
VI South Eastern	.886	.842	-	.871
VII South Central	.860	.818	.749	.801
All Regions	$.864	$.820	$.747	$.808

*Expressed in deflated 1975 dollars per watt.